U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER

DIRECT COAL LIQUEFACTION BASELINE DESIGN AND SYSTEM ANALYSIS

CONTRACT NO. DEAC22 90PC89857

TASK III TOPICAL REPORT:

COST ESTIMATES AND ECONOMICS OF THE BASELINE AND OPTIONS

VOL. II OF II

SEPTEMBER 1992
PITTSBURGH, PENNSYLVANIA

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Bechtel

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September 29, 1992

U. S. Department of Energy
Pittsburgh Energy Technology Center
Mail Stop 922-H
P. O. Box 10940
Pittsburgh, PA 15236

Attention: Mr. Swenam Lee
Project Manager

Subject: D.O.E. Coal Liquefaction
Base Line Design and System Analysis
Contract No. DE-AC22 90PC89857
Bechtel Job No. 20952
Task III Volume I and II, Final Report
Letter No. BLD-112

Dear Mr. Lee:

The Task III Topical/Task report consists of three volumes and addresses the capital and operating costs (volumes I and II) as well as the economics (volume III) of the baseline design and options. This publication, however, consists of a set of two volumes, volumes I and II. The third volume of the Task will be published incorporating the economics of the improved baseline plus the best option and will represent the overall economics for the final report of this study.

Attached for your files are three copies of the subject report. As requested, one of these copies is bound in a loose leaf 3-ring binder for your desk use. Copies to other members of DOE, as required by the contract are transmitted separately and directly.

These two volumes incorporate DOE's comments which appeared on the "draft" issue dated May, 1992 and updated numbers on capital costs and operating requirements for various options.

The report does not contain any confidential information, which as agreed, would have been segregated in the appendix of this report.

Sincerely yours,

Syamal K. Poddar
Project Manager

Attachment

cc: Martin Byrnes, DOE/PETC
Robert Hamilton, DOE/PETC
A. Schachtschneider, AMOCO
File
Gilbert V. McGurl, DOE/PETC
Joanne Wastek, DOE/PETC

The information and data contained in this report are the result of an ecomonic evaluation and a preliminary design effort and because of the nature of this work no guarantees or warranties of performance, workmanship, or otherwise are made, either expressed or by implication.

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INTRODUCTION

INTRODUCTION

The U.S. Department of Energy (DOE) has established a program to "foster an adequate supply of energy at a reasonable cost," in accordance with the National Energy Policy Plan IV (NEPP IV). A cost effective direct coal liquefaction program sponsored by the pittsburgh Energy Technology Center (PETC) is an integral part of NEPP IV.

The overall goal of the coal liquefaction program is "to develop the scientific and engineering knowledge base with which industry can bring economically competitive and environmentally acceptable advanced technology for the manufacture of synthetic liquid fuels from coal.

The present assignment from PETC is undertaken by Bechtel (in collaboration with Amoco as the main subcontractor) to develop a computer model for a baseline direct coal liquefaction design based on two stage direct coupled catalytic reactors. Specifically, the scope of work calls for the development of:

1) a baseline design based on previous DOE/PETC results from Wilsonville pilot plant and other engineering evaluations,

2) a cost estimate and economic analysis, and

3) a computer model incorporating the above two steps over a wide range of capacities and select process alternatives.

In this study, the Topical Reports are also the Task reports. This Topical report (Task III) addresses the capital and operating costs (Volumes I and II) as well as the economics (Volume III) of the direct coal liquefaction study which is primarily based on Wilsonville Pilot Plant data with certain other processing alternates.

Note that Volume III covers the economics of the Improved Baseline plus the Best Option and will, in essence, represent the overall economics for the Final report of this study. For this reason, Volume III of this Task/Topical report has been completely decoupled from the other two volumes and it will be published after the completion of the unnumbered improved baseline economics task.

Therefore, at present this Task/Topical report is published as Volumes I and II of two volumes. The *Table of Contents*, *Introduction* (Section 1) and the *Executive Summary* (Section 2), of Volumes I and II are included in their entirety in both volumes for the reader's reference.

The overall number of topical/task reports for this study are given below as follows:

Task No.	Title
1	Management Plan - one volume
2	Baseline and Alternates Design Development - Volumes I, II and III
3*	Cost Estimate and Economics of the Baseline and Alternates - Volumes I, II and III
4	Development of Mathematical Algorithms and Models for Equipment Sizing, Scale-up, Costing and Train Duplication for Incorporation into the Aspen Simulation Program - one volume
5	Development of an Aspen Process Simulation Model of the Baseline Design and the Alternates - several volumes
6	Development of a Training Manual for the Simulation Model - one volume
(**)	Improved Baseline Design, Cost Estimate, and Modeling
7	Final Report - numerous volumes

* The Task/Topical report is published in two volumes as Volume I and II, the third volume will be published simultaneously with the Improved Baseline report.

** This report will contain the results of the improved baseline design, cost estimate and modeling and therefore will address Tasks 1 through 6.

EXECUTIVE SUMMARY

2. EXECUTIVE SUMMARY

Introduction:

This study is an assignment of Bechtel from the U.S. Department of Energy (DOE)'s Pittsburgh Energy Technology Center (PETC) to develop a computer model for a baseline direct coal liquefaction design based on two stage direct coupled catalytic reactors.

Scope and Technical approach:

The scope of the study and the technical approach to accomplish the overall objective of the study include:

- a baseline design based on previous DOE/PETC results from Wilsonville pilot plant and other engineering evaluations,
- a cost estimate and economic analysis,
- a computer model incorporating the above two steps over a wide range of capabilities and selected process alternatives,
- a comprehensive training program for USDOE/PETC staff to understand and use the computer model,
- a thorough documentation of all underlying assumptions for baseline design and baseline economics, and
- a user manual and training material which will facilitate updating of the model for the future.

Execution Philosophy:

In order to carry out the study efficiently, the study has been divided into seven major tasks with each task having several identifiable subtasks. In Task I the study is defined. The baseline design is developed in Task II. The capital and operating requirements are developed in Task III. Mathematical models for computer simulation are developed in Task IV. Development and Validation of the model is conducted in Task V. Documentation of the process simulation and training program are conducted in Task VI. Whereas, the above mentioned six tasks are functional tasks, the remaining task, Task VII, is a level of effort task for project management, technical coordination and other miscellaneous support functions. Functional tasks are executed by a part time functional group while the project management and technical

coordination (Task VII) are accomplished by a full time core management group.

Topical/Task III Report Contents:

The Task III report is divided into three volumes as follows:

Volumes I and II include capital and operating cost information while Volume III addresses the economics. Volume III of the report will be issued separately at a later date when the improved baseline economics case is developed.

The report starts by setting up the basis and methodology for capital cost estimating and by defining the first plant and Nth plant concepts. The first plant concept, as the name suggests, refers to the first commercial plant design which includes a degree of over-design to meet the name-plate capacity and product specifications. The Nth plant is defined as the commercial plant built N years after the first commercial plant for which the technology basis, plant design, and operation are well established.

In addition, the report describes the methodology used in determining the valuation of products utilizing Bechtel's Process Industry Modeling System (PIMS), a linear programming software. A detailed analysis of reliability and onstream factor for various inside battery limits (ISBL) plants in the complex is also included in the report.

The capital cost (both first plant and Nth plant) and operating requirements for plants 1 thru 25 (Chapters 6 through 23) are included in Volume I whereas similar information for Plants 30 through 42 (chapters 24 through 36) are included in Volume II of the report.

In addition, Volume II contains capital costs information for all seven options (both first plant and Nth plant scenarios). The definition of these options and methodology applied to select them were defined in Volume III of the Topical/Task II report, and are reiterated in Volume II of this report for the reader's convenience.

PLANT 30

24. Plant 30 (Electrical Distribution System)

24.0 Design Basis, Criteria and Considerations

Utility power is supplied by the Steam and Power Generating Plant (Plant 31) at 69 kV to six main switch gear centers.

The electrical generation is supplied by:

- Five trains of combustion turbine generators (CTG) and heat recovery steam generators (HRSG), approximately 410,000 kW total
- Two steam turbine-generator sets (STG), approximately 260,000 kW total
- One 2,500 MVA "Black Start" Diesel Generator

The output from the electrical generating plant (Plant 31) is transformed in the switchyard from 13.8 kV to 69 kV for transmission to the six main substations.

The following table shows the plant loading for the six main substations:

Substation	Plant Loads
Substation 1	Plant No. 9
Substation 2	Plant No. 10 (partial)
Substation 3	Plant No. 10 (partial)
Substation 4	Plants No. 3, 4, 5, 6, 11, 34, 36, 38, and 39
Substation 5	Plants No. 1, 1.4, 8, 24, 32, 41, and 42
Substation 6	Plants No. 2, 19, 20, 25, 33, and 37

All distribution from the substations is expected to be underground duct banks and/or direct-buried cables. However, during detailed design, if required, an overhead distribution system may be adapted.

24.1 Major Equipment List

Due to the nature of this plant, an equipment list is not required as the size and cost will be directly based on the one line diagram.

24.2 Operating Manpower Requirements

There is no dedicated manpower requirement for this plant.

24.3 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 30 are given below in Table 24.1. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 24.1

Plant 30 (Electrical Distribution System)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs Breakdown	Costs ($MM)
Major Equipment	--
Bulk Materials	41.0
Subcontracts	--
Direct Labor	18.0
Distributables (Indirect)	16.2
Total Field Costs	**75.2**

PLANT 31

25. Plant 31 (Steam and Power Generation)

25.0 Design, Basis Criteria and Considerations

The cogeneration plant supplies electric power and 600 psig, 720°F superheated steam to all plants. The cogeneration plant provides self sufficient, sole source power to the complex. Since the power plant is not connected to any grid, Plant 31 has extra installed generating capacity to ensure 100 percent reliability.

A diesel fired generator, 2500 MVA, is used when making a black start. This generator supplies enough emergency electricity to start up a combustion turbine generator and allow the plant to "boot strap" itself up to capacity.

The important design criteria are summarized as follows:

- Primary steam header is 600 psig, 720°F superheated steam
- Five, 84,000 kW (ISO rated) combustion turbine generators
- Five, three pressure level heat recovery steam generators rated at 181,083 pounds per hour high pressure superheated steam (1355 psia, 906°F), and 198,691 pounds per hour intermediate pressure superheated steam (144 psia, 450°F)
- Two extraction, admission, and condensing steam turbine generators rated at 130,000 kW at 1,315 psia, 900°F throttle conditions and 3.5 inch HgA back pressure
- An AC synchronous totally enclosed, water-to-air cooled (TEWAC) generator, rated at 150 MVA and 0.85 power factor for each steam turbine
- An AC synchronous TEWAC generator, rated at 95 MVA and 0.85 power factor for each combustion turbine
- Natural gas is blended with medium BTU gas for the combustion turbines
- Steam output from the plant is 560,000 pounds per hour superheated steam at 600 psig, 720° F.
- Electrical output from the plant is 420,000 kW net

Backup fuel is No. 2 fuel oil (heavy distillate from the complex)

- Generators produce electric power at 13.8 Kv, 3 phase, 60 Hz
- Distribution of electric power from the generators to the main switch-gear centers is 69Kv, 3 phase, 60 Hz

25.1 Major Equipment List

The major equipment list for the plant is included in Table 25.1.

25.2 Catalyst and Chemical Summary

Catalyst and chemicals required for this plant are shown below:

Chemical	Start up quantity	Consumption
30 % Ammonia	7,000 lbs	936 lb/day
Sodium Sulfite	2,000 lbs	240 lb/day
Polymer and Chelant		
Disodium Phosphate	1,000 lbs	144 lb/day

25.3 Operating Manpower Requirements

The operating manpower requirement for this plant is 12 operators. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

25.4 Plot Area Required

The plot area required for the Steam and Power Generating Plant is approximately 1,000 feet by 1,400 feet.

Table 25.1 Major Equipment Summary

STEAM AND POWER GENERATION

Type of Equipment: Vessels and Tanks

Equipment No.	Equipment Description	Length (T-T in ft.)	Diameter (ID in ft.)	Material	Design Conditions Psig	oF	Remarks Capacity (hrs)	Capacity (gal)	No. of Vessels
31-D101A/B	Fuel Oil Day Tanks	40	50	C.S.	100	100	24	650,000	2
31-D102A/B	Condensate Storage Tank	30	30	C.S.	100	100	24	150,000	2
31-D103	CCW Head Tank	12	6.5	C.S.	150	100	N/A	3,000	1
31-D104	Emergency Diesel Gen. Fue	9	13	C.S.		100	48	8,800	1
31-D105	Fuel Gas Scrubber Tank	4	3	S.S.	0	100	N/A	200	2
31-D106A-E	Inlet Gas Scrubber	8	3	S.S.	500	100	125,000 SCFM		5

Table 25.1 Maj r Equipm nt Summary - c ntinued

EQUIPMENT LIST OF PLANT 31 - STEAM AND POWER GENERATION

Type of Equipment: Heat Exchangers

Equipment No.	Equipment Description	Duty (MM Btu/hr)	Type of Exchanger	Tube Material	Tube Desig psig/oF	Shell Material	Shell Desi psig/oF	Area Ft2	No. of Exch.
31-E101A-E	Heat Recovery Steam Generators with Duct Burners and Deaerator	468		S.S.	1500HI 150IP /1500	C.S.	Atm/100	545,000	5
31-E102A/B	Steam Turbine Surface Condensers	1520		S.S.	50/200	C.S.	3.5" Hg/95	91,137	2
31-E103	Turbine Dump Condenser	2550		S.S.	50/200	C.S.	3.5" Hg/95	150,868	1
31-E104A/B	CCW Heat Exchangers	30			150/150				2

Table 25.1 Maj r Equipment Summary - c ntinued

EQUIPMENT LIST OF PLANT 31 - STEAM AND POWER GENERATION

Type of Equipment: Pumps

Equipment No.	Equipment Description	Flow Rate GPM	Delta Press PSIa	Brake HP	Design Conditions Pres (psig)	Design Conditions Temp (oF)	Driver	Est. Drive HP	No. of Pumps
31-G101A-D	Hotwell Condensate Pumps	3,200	994.4	249	100	200	Elec	300	4
31-G102A-F	HRSG Feed Pumps	690	583.7 58.4	731	1500/150	300	Elec	750	5
31-G103A-D	Circulating Water Pumps	83,820	43.2	2647	50	95	Elec	3000	4
31-G104A/D	Circulating Water Booster Pumps	17,600	34.6	445	85	95	Elec	500	4
31-G105A/B	Closed Cooling Water Pumps	3,000	86.5	189	150	115	Elec	200	2
31-G106A/B	Dump Condenser Condensate pumps	4,120	99.4	321	100	400	Elec	350	2
31-G107A-F	Condenser Vacuum Pumps	25 SCFM		100	1.0" Hg	95	Elec	100	6
32-G108A/B	High Pressure Steam Generator Pumps	700	650.0	371	750	550	Elec	400	2
32-G109A/B	Medium Pressure Steam Generator Pumps	3,200	200.0	522	300	425	Elec	600	2
32-G110A/B	Low Pressure Steam Generator pumps	2,300	100.0	188	150	350	Elec	250	2

Tabl 25.1 Maj r Equipment Summary - continued

EQUIPMENT LIST OF PLANT 31 - STEAM AND POWER GENERATION

Type of Equipment: Steam and Turbine Generators

Equipment No.	Equipment Description	Design Power MV	Design PSIG HP/IP/LP	Design F HP/IP/LP	Main Stm Flow MLb/hr	Admission STM Flow MLb/hr	Exhaust STM Flow MLb/hr	No. of STM GEN
31-K101A/B	Steam Turbine - Generators	130	1300/125 /-13	900/444 /121	1,002	700	1,252	2

Equipment No. Number	Equipment Description	Design Power MV	Design Air Temp F	Air Flow MLb/hr	Exhaust Temp F	Turbine Exhaust MLb/hr	Turbine Exhaust F	No. of COMB GEN
31-K102A-E	Combustion Turbine - Generators	82	95	2,100	705	2,150	1,075	5
31-K103	Emergency Diesel Generato	2						1

Type of Equipment: Miscellaneous

Equipment No.	Equipment Description	Flow Rate	Other Design Criteria	Design Conditions Pres (psig)	Temp (oF)	Driver	Est. Drive HP	No. of Equip.
31-T101	Turbine Building Bridge Crane		75 tons, Width 65, CS					1

25.5 Capital Cost and Breakdowns

The field costs and breakdowns for Plant 31 are given below in Table 25.2. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 25.2

Plant 31 (Steam and Power Generation)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs Breakdown	Costs ($MM)
Major Equipment	180.4
Bulk Materials	33.3
Subcontracts	3.2
Direct Labor	33.2
Distributables (Indirect)	29.9
Total Field Costs	**280.0**

PLANT 32

26. Plant 32 (Raw, Cooling and Potable Water)

26.0 Design Basis, Criteria and Considerations

Raw Water Treatment

The principal source of raw water for the plant is from the nearby lake or river. The raw water treatment consists of:

- Clarification of water
- Gravity filtration
- Potable water chlorinator
- Demineralization

Clarified water is used for cooling tower makeup, fire fighting and utilities.

A package potable water system is used to treat water used for drinking, food preparation and sanitary facilities. This water has been clarified and filtered.

Boiler feed water has been clarified, filtered and demineralized.

Reactor/clarifiers are used to clarify the water. These units produce a much thicker sludge than is possible in a conventional clarifier. The thickened sludge can be pumped directly to a sludge dewatering press without the need of a thickener.

Raw water analysis is shown in Table 26.1. For raw water with these given quality (as shown in Table 26.1) conventional cold lime softening and soda ash treatments are not needed to reduce the content of calcium and magnesium as carbonate. Sodium aluminate and a polymer are added to aid settling of the suspended solids. The softened effluent does not require a pH adjustment.

TABLE 26.1

RAW WATER ANALYSIS FOR DESIGN

Water Properties	Mid Continent Location	
NAME	**AVERAGE**	**MAXIMUM**
RAW WATER		
Temperature, °F (Range)	40 -- 89	
pH	6	8.5
Calcium as CaCO3, ppm	140	180
Calcium as Ca, ppm	38	49
Magnesium as $MgCO_3$, ppm	96	130
Bicarbonate as HCO_3, ppm	137	173
Sulfate as SO_4, ppm	350	570
Silica as SiO_2, ppm	6.5	7.0
Total Dissolved Solids, ppm	662	1,449
Conductivity, MOH	1,000	1,200
Turbidity, Jackson Turbidity Units (JTU)	---	20
Clarified Water		
Turbidity, JTU units		3

The clarified water is filtered using two dual filter media gravity filters. The required amount of the filtered water is fed to a potable water chlorinator system and the rest goes to the demineralizer. The balance of the clarified water goes to storage tanks.

Sludge resulting from the clarification (clarifier underflow) is filtered with a filter press and the filter cake is sent to an approved landfill. The small flow of filtrate water is recirculated back to the reactor/clarifier.

Cooling Water System

One conventional, wood cross flow tower with splash type fill cooling water system with mechanical induced-draft cooling tower is provided.

The cooling tower is designed to supply the cooling requirement of the process plants.

An objective of the cooling water system design is to minimize the use imported water for cooling tower makeup. This results in maximizing the reuse of treated process waste water, including cooling tower makeup. The rest of makeup water is supplied with clarified water.

The cooling tower capacity is as follows:

Duty	=	3,923 MMBTU/Hr
Inlet Temperature	=	115°F
Outlet Temperature	=	87°F
Circulation Rate	=	280,000 GPM
Water Evaporation Loss	=	0.1% x Delta T Ave.
Drift Loss	=	0.1%
Blowdown	=	4 Cycles

Cooling water system is designed for a supply water temperature of 87°F.

The climatic conditions used for the cooling tower design are:

- Atmospheric press = 14.3 psig
- Air Temperatures
  - Inlet temperature: -6 to 95°F
  - Wet Bulb Temperature: 78°F
  - Dry Bulb Temperature: 95°F at 45% Relative Humidity

Cooling Tower Makeup

Makeup water to the cooling tower is clarified raw water and treated process waste water from Plant 34.

Cooling Water Requirement

The design cooling requirements for the complex, including power and steam generator plant (Plant 31) is served by an 18 cell cooling tower two spare cells.

26.1 Major Equipment Summary

Major Equipment Summary is listed in Table 26.2.

26.2 Catalyst and Chemical Summary

Catalyst and chemicals required for this plant is shown below:

Chemical	Required for Start up	Consumption
Alum	30,000 lbs	4,680 lb/day
Polymer	2,000 lbs	156 lb/day
98% H_2SO4	15,000 gals	15,680 lb/day
50% NaOH	30,000 gals	38,754 lb/day
Polymeric Dispersion	7,000 lbs	1,624 lb/day
Non-ionic Surfactant		

26.3 Operating Manpower Requirements

The operating manpower requirement for this plant is 4 operators. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

26.4 Plot Area Required

The plot area required for the Raw, Cooling and Potable Water Systems is approximately 200 feet by 1,000 feet plus about 60 acres for raw water storage.

Table 26.2
Major Equipment Summary

Type of Equipment: Vessels and Tanks

Equipment No.	Equipment Description	Length (T-T in ft.)	Diameter (ID in ft.)	Material	Design Conditions Psig	oF	Remarks	No. of Vessels
32-D101	Rapid mix tank with high speed mixer	20	10	CS	10	100	15 HP mixer	1
32-D104	Alum feed day tank	15	7.5	CS	10	100	5000 Gallons	1
32-D105	Polymer feed day tank	10	4	CS	10	100	1000 Gallons	1
32-D106	Cake storage bin			CS	ATM	100	10'x12'x12'	1
32-D107A/B	Clarified water storage tanks	48	200	CS	ATM	100	API STD TANK	2
32-D108A/B	Deminerlized water storage tanks	40	60	CS	ATM	100	API STD TANK	2
32-D109	Potable water storage tank	48	30	CS	ATM	100	API STD TANK	1
32-D110	Caustic tank	25	20	CS	10	200		1
32-D111	Acid tank	20	15	SS	10	200		1

Type of Equipment: Heat Exchangers

Equipment No.	Equipment Description	Duty (MM Btu/hr)	Type of Exchanger	Tube Material	Tube Design psig/oF	Shell Material	Shell Design psig/oF	Area Ft2	No. of Exch.
32-E101A-R	Cooling Towers 18 + 2 spare cells	157	Wood crossflow with splash type fill. total capacity 180,000 gals/hour.						18

Tabl 26.2 Major Equipment Summary - continu d

Type of Equipment: Pumps

Equipment No.	Equipment Description	Flow Rate GPM	Delta Pres PSIa	Brake HP	Design Conditions Pres (psig)	Design Conditions Temp (oF)	Driver	Est. Driver HP	No. of Pumps
32-G101A-F	Cooling Tower Pumps 5 + 1 spare	40,000	65	2121	75	100	Elec	2500	9
32-G102A-D	Clarifier sludge recycle pumps (no spare)	25	15	2	50	100	Elec	5	4
32-G103A-D	Filter press sludge feed pumps (2 spare)	150	50	6	75	100	Elec	10	4
32-G104A/B	Alum feed pumps (one spare)	2	50		75	100	Elec	1	2
32-G105A/B	Polymer feed pumps (1 spare)	5	50		75	100	Elec	1	2
32-G106A/B	Gravity filter backwash pumps (1 spare)	1200	30	29	50	100	Elec	50	2
32-G107A-C	Deminerlizer feed water pumps (1 spare)	550	75	34	50	100	Elec	50	3
32-G108A-C	Degasified water transfe pumps (1 spare)	550	76	34	50	100	Elec	50	3
32-G109A-C	Raw water intake pumps (one spare)	7000	15	86	50	100	Elec	100	3
32-G110A-C	Clarified water stg feed pumps (one spare)	6400	31	162	50	100	Elec	200	3
32-G111A-C	Clarified water transfer pumps (one spare)	6400	75	392	100	100	Elec	500	3
32-G112A/B	Deminerlized wtr trans. pumps (one spare)	1100	50	45	75	100	Elec	50	2
32-G113A/B	Potable water transfer pumps(one spare)	120	75	7	100	100	Elec	10	2
32-G114A/B	Caustic metering pumps (one spare)	1	75	0	100	200	Elec	1	2

Table 26.2 Major Equipment Summary - continued

Type of Equipment: Air Blow rs

Equipment No.	Equipment Description	Flow Rate (ACFM)	Diff Pres (psi)	Brake Horsepower	Design Conditions Pres (psig)	Design Conditions Temp (oF)	Driver	Est. Driver HP	No. of Equip.
32-K101A-R	Cooling Tower Fans (16 + 2 Spare)			189			Elec	200	27
32-K102	Forced draft degasifier			1.2			Elec	2	1

Type of Equipment: Miscellaneous

Equipment No.	Equipment Description	Flow Rate	Other Design Criteria	Design Conditions Pres (psig)	Design Conditions Temp (oF)	Driver	Est. Driver HP	No. of Equip.
32-Z101A/B	Clarifier/Reactors with mixers	7000	Two Mixers	ATM	100	Elec	10	2
32-Z102A/B	Gravity filters			ATM	100			2
32-Z103	Potable water gas chlorinator							1
32-Z104A-C	Strong acid cation exchangers (1 spare)	1100	ASME	100	150			3
32-Z105A-C	Strong base anion exchangers (1 spare)	1100	ASME	100	150			3
32-Z106	Acid regeneration system		one acid bulk tank two acid pumps			Elec	1	1
32-Z107	Caustic regeneration system		one caustic bulk tank, 2 caustic pumps, one steam heater			Elec	1	1
32-Z108A-C	Mixed bed polishers (one spare)			75	150			3
32-Z109A/B	Sludge filter press			100	100			2
32-Z110	Cooling tower chemical treat package		Nalco tower master plus Liquid metering pump, Water meter					1

26.5 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 32 are given below in Table 26.3. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 26.3

Plant 32 (Raw, Cooling and Potable Water Systems)

Field Costs and Breakdowns (First & Nth Plants) 2nd Quarter, 1991

Field Costs & Breakdowns	Costs ($MM)
Major Equipment	17.5
Bulk Materials	7.5
Subcontracts	4.9
Direct Labor	6.8
Distributables (Indirect)	6.1
Total Field Costs	**42.8**

PLANT 33

27. Plant 33 (Fir Protection Systems)

27.0 Design Basis, Criteria and Considerations

Fire protection and control systems for all facilities, structures and equipment within the plant area are designed in compliance with federal, state, and local jurisprudence codes and standards and with the recommendations of the American Petroleum Institute, National Fire Protection Association, Industrial Risk Insurer, and the Oil Insurance Association (OIA).

A comprehensive fire water system is provided for the general fire protection of the entire plant. Chemical and steam fire suppression systems are provided for specific facilities and equipment. These systems cover:

Fire water to process plants, coal handling, water and waste treatment, and storage tankage

Fireproofing for vessel supports, pipe racks, etc.

Sprinkler systems for buildings, part of the process equipment such as pumps or heat exchangers (depending on the location), tank truck, tank car, filling rack

Smothering steam for compressor buildings and fired heaters

Halogen system for computer room and laboratory

Nitrogen system for sulfur storage tanks

27.1 Major Equipment Summary

Equipment No.	Type	Description
33.1D-101	Fire Water Tank	105' x 40' 50,000 bbl capacity, cone roof API-650
33.1G-101	Fire Water Main Pump	3500 gpm, 193 psi diff. press., 503 Bhp, 240 psig and 100°F design P&T, electric motor/steam turbine drivers, vertical
33.1G-102	Fire Water Main Pump	3500 gpm, 192 psi diff. press., 503 Bhp, 240 psig and 100°F design P&T, diesel engine driver, vertical
33.1G-103	Fire Water Main Pump	3500 gpm, 174 psi diff. press., 503 Bhp, 240 psig and 100°F design P&T, electric motor/steam turbine drivers, horizontal
33.1G-104	Fire Water Main Pump	3500 gpm, 174 psi diff. press., 503 Bhp, 240 psig and 100°F design P&T, diesel engine driver vertical
33.1G-105A	Fire Water Jockey Pump	275 gpm, 192 psi diff. press., 50 Bhp, 240 psig and 100°F design P&T, electric motor
33.1G-105B	Fire Water Jockey Pump	275 gpm, 192 psi diff. press., 50 Bhp, 240 psig and 100°F design P&T, electric motor

Equipment No.	Type	Description
33.3V-101	Foam to Gas. Ref.,	Skid mounted foam Phenol & Raw Heavy subsurface injection Naphtha system including 3000 gal. C.S. storage drum, 300-2200 GPM foam proportioner, 550 gpm foam maker nozzles
33.4V-102	Aer-O-Foam Dry Mobile Dry Chemical Pump	Chemical Pump and trailer, capacity 1500 GPM at 6% rate

27.2 Operating Manpower Requirements

The operating manpower requirement for this plant is 5 operators. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

27.3 Plot Area Required

The plot area required for the fire protection systems is approximately 150 feet by 200 feet.

27.4 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 33 are given below in Table 27.1. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 27.1

Plant 33 (Fire Protection Systems)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	2.7
Bulk Materials	5.3
Subcontracts	0.2
Direct Labor	7.5
Distributables (Indirect)	6.8
Total Field Costs	**22.5**

PLANT 34

28. Plant 34 (Sewage and Effluent Water Treatment)

28.0 Design Basis, Criteria and Considerations

Wastewater Treatment (Plant 34) and Water Systems (Plant 32) are closely related and together constitute the Project Water Management System, with the purpose of minimizing both raw water consumption and effluent discharge to public waters during normal plant operation. Waste water streams are segregated on the basis of their compatibility and treated as necessary to make them suitable for reuse, if practical, in lieu of fresh water.

The majority of the water used in the project eventually goes to the atmosphere as water vapor. Some water is disposed of as moisture associated with the solid wastes going to the land fills.

Individual systems described in this section include:

- Coal Storage Pile Runoff Treatment
- Oily Wastewater Treatment
- Deoiled Wastewater Treatment
- Stripped/Dephenoled Wastewater Treatment
- Solids Dewatering
- Sanitary Sewage Treatment

The design basis, process description and block flow diagrams for each of the above treatment systems are given under each treatment system described herein. The major equipment list and utility summary are shown for the combined treatment systems in subsections 28.7 and 28.8, respectively.

28.1 Major Equipment Summary

A summary of the major equipment for Plant 34 is shown in Table 28.1

28.2 Catalyst and Chemical Summary

Catalyst and chemicals required for this plant is shown below:

Chemical	Required for Start up	Consumption
Chlorine	2,000 lbs	350 lb/day
Polymer	3,000 lbs	450 lb/day
PAC	6,000 lbs	2,000 lb/day

Tabl 28.1

Major Equipment Summary

PLANT 34 – WASTE WATER TREATMENT

Equipment No.	BFD No.	Type	Description
34-C101A,B	2	Air Solution Vessel	1,350 gal
34-D101	1	Polymer Solution Tank	57 in. dia. X 64 in., 480 gal nom. cap.
34-D102	1	Soda Ash Solution Tank	240 gal, 42 in. dia. X 46 in.
34-D103	1	Filter Backwash Make-up Tank	8.5 ft. dia. X 6 ft., 1,700 gal
34-D104	6	Sewage Lift Sump	4 ft. X 7 ft. X 10 ft. deep, concrete
34-D105	2	Alum Day Tank	900 gal, 64 in. dia. X 72 in.
34-D106	2	Flow Splitter Sump	24 ft. X 9 ft. X 12 ft., concrete
34-D107	2	Polymer Solution Tank	64 in. dia. X 72 in., 900 gal
34-D108	2	Skimmed Oil Settling Tank	675 bbl, 14 ft. dia. X 24 ft.
34-D109	2	Caustic Soda Day Tank	64 in. dia. X 72 in., 900 gal
34-D110	2	Acid Day Tank	64 in. dia. X 72 in., 900 gal
34-D111	2	Flash Mix Tank	6 ft. dia X 11 ft.
34-D112	2	Flocculation Tank	29 ft. dia. X 10 ft.
34-D113	2	Oily Sludge Sump	9 ft. X 9 ft. X 10 ft. deep
34-D114	3	Filter Feed Tank	72 ft. X 80 ft. X 15 ft. deep, concrete, 646,000 gal
34-D115	3	Polymer Storage Tank	135 gal
34-D116	3	Polymer Mixing Tank	270 gal
34-D117	3	Polymer Feed Tank	270 gal
34-D118	4	Equalization Tank	72,000 bbl, cone roof
34-D119A,B	4	PAC Storage Tank	14 ft. dia. X 10 ft., 1539 cu. ft.
34-D120	4	PAC Slurry Tank	800 gal with 2 hp mixer
34-D121	4	Nutrient (H3PO4) Feed Tank	10000 gal, fiberglass
34-D122	5	Filtrate Supply Tank	4 ft. dia. X 6 ft.
34-D123	5	Sludge Surge Tank	10 ft. dia. X 15 ft.
34-E111	2	Skimmed Oil Tank Heater	2.7 MMBTU/hr

Sheet 1

Table 28.1 Major Equipment Summary - continued

PLANT 34 – WASTE WATER TREATMENT

Equipment No.	BFD No.	Type	Description
34-G101A,B	1	Surge Basin Lift Pump	300 gpm, 3.0 bhp
34-G102	1	Polymer Feed Pump	0-4 gpm, 1 hp
34-G103	1	Soda Ash Feed Pump	0-0.15 gpm, 1/3 hp
34-G104A,B	1	Sludge Pump	60 gpm, 1.5 bhp
34-G105A,B	1	Clarified Effluent Pump	300 gpm, 15 bhp
34-G106	1	Filter Backwash Pump	860 gpm, 6 bhp
34-G107A,B	6	Lift Pump	Submersible, centrifugal, 200 gpm, 7 bhp
34-G108	6	Froth Spray Feed Pump	3/4 hp, 30 gpm at 15 ft. TDH
34-G109	6	Digested Sludge Drawoff Pump	5 gpm, 1/4 bhp
34-G110A,B	2	Screw Lift Pump	150 – 1,500 gpm, 15 bhp
34-G111A,B	2	Alum Feed Pump	Wallace and Tiernam Series 44 or equivalent, 0-7 gpm @ 20 ft. head
34-G112A,B	2	Oil Transfer Pump	135 gpm, 50 psi differ., horizontal, centrifugal
34-G113A,B	2	Polymer Feed Pump	0-4 gpm, 1 bhp
34-G114A,B	2	Caustic Soda Feed Pump	0-1.5 gpm, 1 bhp
34-G115A,B	2	Skimmed Oil Pump	67 gpm, 1.5 bhp
34-G116A,B	2	API Sludge Pump	14 gpm, 1.5 bhp
34-G117A,B,C	2	API Separator Effluent Pump	1,350 gpm, 30 bhp
34-G118A,B	2	Acid Feed Pump	0-0.75 gpm, 1/3 bhp
34-G119A,B,C	2	Recycle Pressuring Pump	675 gpm, 35 bhp
34-G120A,B	2	DAF Bottom Sludge Pump	20 gpm, 3/4 bhp
34-G121A,B	2	Oily Sludge Sump Pump	35 gpm, 4 bhp
34-G122A,B	3	Sludge Pump	1350 gpm, 55 bhp
34-G123A,B	3	Sludge Thickener Pump	7 gpm, 3/4 hp
34-G124A,B	3	Polymer Feed Pump	0.2-1.5 gpm, 1 hp
34-G125A-C	3	Filter Feed Pump	1350 gpm, 70 bhp

Sheet 2

Table 28.1 Major Equipment Summary - continued

PLANT 34 - WASTE WATER TREATMENT

Equipment No.	BFD No.	Type	Description
34-G126A,B	3	Filter Backwash Pump	1000 gpm, 15 bhp
34-G127A,B	4	PAC Feed Pump	20 gpm, 1.5 hp
34-G128A,B	4	Sludge Recycle Pump	2200 gpm, 150 hp
34-G129A,B	4	Waste Sludge Pump	120 gpm, 4 hp
34-G130	4	Nutrient (H3PO4) Metering Pump	2-20 GPH
34-G131A,B	3	Polymer Transfer Pump	14 gpm, 3/4 hp
34-G132A,B	5	Sludge Pump	0-100 gpm
34-G133A,B	5	Filtrate Return Pump	100 gpm
34-J101	1	Feed Pump Controller	Processes 2 remote signals, controls a 1/4 hp D.C. motor
34-K101	1	Filter Backwash Air Blower	120 SCFM @ 30 psig, 20 bhp
34-K102A,B	6	Air Blower	V-belt driven, 15 hp, 1750 rpm
34-K103A,B	2	Air Compressor	15 SCFM at 50 psig, 3-1/2 bhp
34-K104A-F	3	Marox Aerators	15 hp, 2000 1b. O2 dissolved per day
34-K105A,B	3	Filter Backwash Air Blower	135 SCFM at 30 psig, 20 bhp
34-K106A,B	4	Oxygen Supply Compressor	9600 SCFM @ 75 psia, 100°F, 2400 bhp
34-Q101	2	Surge Pond Lift Pump Sump	35 ft. X 7 ft. X 17 ft. deep
34-R101	5	Press Building	30 ft. X 30 ft. X 30 ft.
34-V101	6	Sanitary Sewage Treatment Pkg	Model HS-150 Hydro-Robic Treatment Plant or Equivalent, Hydro Systems, Inc., Portland, TN, Treats 150,000 gpd of sanitary sewage
34-V102A,B	2	Dissolved Air Flotation System	Consists of a circular flotator, pressurizing pumps, air satur. vessel, air compressor, and pressure relief valve
34-V103	4	Polymer Feed System	2-20 GPH
34-V104A,B	5	Polymer Feed System	1-10 GPH
34-Y101	2	Alum Mixer	1 bhp, 350 rpm

Sheet 3

Tabl 28.1 Major Equipment Summary - continued

PLANT 34 – WASTE WATER TREATMENT

Equipment No.	BFD No.	Type	Description
34-Y102	2	Polymer Mixer	1 bhp, 350 rpm
34-Y103	2	Flash Mixer	100 rpm, 2.5 bhp
34-Y104	2	Flocculation Mixer	8 ft. dia., 1.5 bhp
34-Z101	1	Polymer Mixer	1 hp, 350 rpm
34-Z102	1	Reactor Clarifier	40 ft. dia.
34-Z103A,B	1	Media Filters	76 in. dia.
34-Z104	6	Aeration Compartment	7160 cu. ft., 9 hr min. detention time at design flow rate
34-Z105	6	Aerobic Digester	3460 cu. ft., 4 hr min. detention time at design flow rate
34-Z106	6	Clarifier Settling Tank	226 sq. ft., 4 hr detention time at design flow
34-Z107	6	Airlift System	Transports activated sludge and waste sludge
34-Z109	6	Comminutor	1/2 hp, reduce and screen organic matter to 1/4 in. or less
34-Z110	6	Froth Spray System	For deaeration compartment and aerobic digester
34-Z111	6	Chlorine Contact Tank	3,360 gal
34-Z112	6	Chlorinator	Max. capacity 30 lbs CL2 per 24 hr, Regal model 410-B or equivalent
34-Z113	2	API Separator	2 channel, 5 ft. deep X 13 ft. wide X 135 ft. long
34-Z114	2	Oil Skimming Equip. for API Separ.	
34-Z115A,B	2	Flotators	35 ft. dia. X 7 ft.
34-Z116A,B,C	3	Aeration Basin	92 ft. X 35 ft. X 18 ft. deep
34-Z117A,B,C	3	Clarifier	69 ft. dia.
34-Z118	3	Sludge Thickener	11.5 ft. dia.
34-Z119	3	Chlorine Feeder	13.5 lb CL2/hr
34-Z120A-D	3	Media Filters	10 ft. dia., dual media pressurized filtration modules

Sheet 4

Table 28.1 Major Equipment Summary - continued

PLANT 34 - WASTE WATER TREATMENT

Equipment No.	BFD No.	Type	Description
34-Z121A,B,C	4	Wet Oxidation System	Zimpro Wet Oxidation Package. Consists of 2 feed pumps, 2 high pressure pumps, 1 O2 compressor, 1 process heater, 1 start-up heater, 1 reactor, 1 gas-liquid separator, 1 gas scrubber, and 2 high pressure purge pumps
34-Z122A,B	4	PAC Feeders	4000 lb PAC/hr
34-Z123A-E	4	Aeration Basin	42 ft. X 224 ft. X 18 ft. deep, concrete
34-Z124A-C	4	Clarifier	70 ft. dia.
34-Z133A-F	4	Aerator	20 hp motor, 3000 lb O2/day
34-Z134A-F	4	Aerator	20 hp motor, 3000 lb O2/day
34-Z135A-F	4	Aerator	20 hp motor, 3000 lb O2/day
34-Z136A-F	4	Aerator	20 hp motor, 3000 lb O2/day
34-Z137A-F	4	Aerator	20 hp motor, 3000 lb O2/day
34-Z138	4	Thickener	14 ft. X 14 ft.
34-Z139A,B	5	Belt Press	1 m size

28.3 Operating Manpower Requir ments

The operating manpower requirement for this plant is 34 operators. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

28.4 Plot Area Required

The plot area required for the entire Sewage and Effluent Water Treatment Systems is approximately 500 feet by 1,200 feet.

28.6 Capital Cost and Br akdowns (First & Nth Plant)

The field costs and breakdowns for Plant 34 are given below in Table 28.2. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 28.2

Plant 34 (Sewage and Effluent Water)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	7.9
Bulk Materials	10.2
Subcontracts	0.7
Direct Labor	15.1
Distributables (Indirect)	13.6
Total Field Costs	**47.5**

PLANT 35

29. Plant 35 (Instrument and Plant Air Faciliti s)

29.0 Design Basis, Criteria and Considerations

The facilities include all equipment necessary to supply instrument and utility air to the process plants and support facilities. Distribution piping is included in Plant 21 (Interconnecting Piping)

Instrument and utility air is dry, oil-free and dirt-free at the following design conditions:

- Pressure 100 psig
- Temperature 100°F
- Dew Point -40°F
- Ambient air summer dry bulb temperature, 95°F
- Ambient air summer wet bulb temperature, 89°F
- Ambient air winter temperature, -6°F
- Ambient air extreme temperatures, -18°F and 104°F

The system consists of three packaged air compressors, two operating and one spare, to supply the requirement of 15,000 inlet scfm. Auxiliary equipment such as filters, knockout drums, air dryer packages, filters and air coolers are included.

29.1 Major Equipment List

Item Number	Item Description
35	Instrument Air and Plant Air System
35-C101A	Air Knockout Drum
35-C101B	Air Knockout Drum
35-K101A	Plant Air Compressor Package
35-K101B	Plant Air Compressor Package
35-K101C	Plant Air Compressor Package
35-V101A	Air Dryer Package
35-V101B	Air Dryer Package

29.2 Operating Manpower Requirements

There is no special operating manpower allocation for this plant. This is covered by the manpower allocated to the adjacent plant.

29.3 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 35 are given below in Table 29.1. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 29.1

Plant 35 (Instrument and Plant Air Facilities)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	2.7
Bulk Materials	1.8
Subcontracts	--
Direct Labor	2.5
Distributables (Indirect)	2.3
Total Field Costs	**9.3**

PLANT 36

30. Plant 36 (Purge and Flush Oil System)

30.1 Design Basis, Criteria and Considerations

Plant 36 delivers a light and heavy flush oil for pump seal flush and instrument purge. Seal flush and instrument purge are required on a continuous basis for plant areas where high solid (crushed coal and coal ash) content fluids are being transported. In these areas, each pump seal receives a specified flow of flush oil into seal housings, preventing solids from blocking the flow of lubricating fluids at sealing surfaces. Without the seal flush, pumps in these areas could fail in a few hours due to improper lubrication.

Likewise, each instrument receives a specified flow of light flush oil into instrument lines, preventing solids from blocking the lines and rendering the instruments (alarms, gauges, meters, etc.) ineffective.

Coal liquefaction (Plant 2) is the only plant requiring seal flush and instrument purge due to high quantities of coal and coal ash in several streams.

Both the light and heavy flush oils are obtained from Coal Liquefaction (Plant 2) and stored, filtered, and delivered to offsite Tankage (Plant 20). Interconnecting Piping (Plant 21) is utilized to transfer the flush oils to specific applications.

The light flush oil is obtained from the mixture of two Plant 2 streams: the atmospheric tower side stream and the overhead from the vacuum tower. The heavy flush oil is obtained from a vacuum tower side stream. Tables 30.1 and 30.2 summarize the flow requirements for both flush oils. Only light flush oil is used for instrument purge, and most of the pump seal flush utilizes the heavy flush oil. Light and heavy flush oil consumption is based on 0.25 gpm per instrument and 2.5 gpm per pump seal including spare pumps.

TABLE 30.1

LIGHT FLUSH OIL USAGE

APPLICATION	FLOW (GPM)
Instrument Purge	36
Seal Flush	45
Total	81

TABLE 30.2

HEAVY FLUSH OIL USAGE

APPLICATION	FLOW (GPM)
Instrument Purge	0
Seal Flush	263
Total	263

30.2 Capital Cost and Br akdown (First & Nth Plant)

The field costs and breakdowns for Plant 36 are given below in Table 30.3. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 30.3

Plant 36 (Purge and Flush Oil System)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Beakdowns	Costs ($MM)
Major Equipment	1.0
Bulk Materials	7.0
Subcontracts	--
Direct Labor	3.8
Distributables (Indirect)	3.4
Total Field Costs	**15.2**

PLANT 37

31. Plant 37 (Solid Wast Manag ment)

31.0 Design Basis, Criteria and Considerations

This plant disposes of wastes from Raw, Cooling, and Potable Water (Plant 32), Wastewater Treatment (Plant 34), and miscellaneous sources which include plant refuse and flotsam.

All the solid waste excluding the miscellaneous plant refuse is stored in bins and hoppers and collected daily to minimize onsite storage. Once collected, it is transported to an approved landfill disposal site outside battery limits in off-road trucks.

Table 31.1 below summarizes the quantities of solid wastes.

Table 31.1
Solid Waste Summary

Waste Source	Waste Type	Waste Flow Rate (TPD)
Raw, Cooling, and Potable H2O (Plant 32)	Filter Cake	24
Wastewater Treatment (Plant 34)	Filter Cake, Sludge, Salts	96
Miscellaneous	Plant Refuse, Flotsam	5

Dewatering of the solid wastes identified above occurs within the battery limits of the source plant. Descriptions of these facilities are included in the source plant process descriptions.

Miscellaneous plant refuse and flotsam is stored in dumpsters. The estimated number of these containers required for the entire plant is 30. Conventional rear loader compactor trucks are used to transport this waste to the approved landfill site outside battery limits. These trucks are fully compatible with the wheeled, rear loader dumpsters used for storage. The trucks make one trip to the disposal site each day.

31.1 Major Equipment Summary

Equipment No.	Type	Size or Capacity
37-T101	Off-road rear dump hauler	40 ton
37-T102	Off-road rear dump hauler	85 ton
37-T103A-Z, T104A-D	Rear loader dumpsters	4 yd^3
37-T105A,B	Conventional rear loader, municipal type, compactor trucks	25 yd^3

31.2 Operating Manpower Requirements

The operating manpower requirement for this plant is 4 operators. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

31.3 Plot Area Required

The plot area required for the waste bins, hoppers, and dumpsters is included in the appropriate plant.

31.3 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 37 are given below in Table 31.2. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 31.2

Plant 37 (Solid Waste Management)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	2.4
Bulk Materials	--
Subcontracts	--
Direct Labor	--
Distributables (Indirect)	--
Total Field Costs	**2.4**

PLANT 38

32. Plant 38 (Ammonia Recov ry)

32.0 Design Basis, Criteria and Considerations

Ammonia Recovery (Plant 38) and Phenol Recovery (Plant 39) are closely related and together constitute the Project Sour Water Stripping, with the purpose of minimizing both raw water consumption and effluent discharge to public waters during normal plant operation. Sour water streams are segregated and treated as necessary to make them suitable for reuse, if practical, in lieu of fresh water.

Sour Water Treating

ARISTECH PHOSAM-W is a development technology of USX Corporation, licensed by USX Engineers and Consultants Inc. (UEC). The process removes free ammonia and acid gases from the sour waters. In the absorber the ammonia is chemically absorbed from the sour water stripper vapors by a circulating water solution of ammonium phosphate.

In the stripper, the ammonia is recovered from the solution and the solution is regenerated for feed to the absorber.

The aqueous ammonia vapor from the stripper overhead is condensed and fed to the fractionator where it is distilled under pressure to produce a high quality anhydrous product.

Design Basis

The capacity of the PHOSAM-W unit is 4000 GPM of concentrated sour water from the Coal Liquefaction Plant (Plant 2). This allows approximately 10 percent spare capacity to permit work-off of sour water produced during non scheduled shutdowns. Tankage for five days storage of sour water feed is also provided to smooth out operations of the PHOSAM-W plant. There are 243.8 TPSD of anhydrous ammonia recovered in this process. The yields are based on the Breckinridge Initial Effort plant and have been reviewed by the licensor and deemed as reasonable.

32.1 Major Equipment Summary

The Equipment Summary for PHOSAM-W Ammonia Recovery is shown in Table 32.1.

Table 32.1 Major Equipment Summary

Type of Equipment: Columns and Drums		
Equipment No.	Equipment Description	Number Required
38-C-101	Sour Water Stripper	3
38-C-102	Ammonia Absorber	1
38-C-103	Contactor	1
38-C-104	Stripper	1
38-C-105	Fractionator	1
38-C-106	Fractionator Feed Drum	1
38-C-107	Fractionator R/F Drum	1
38-C-108	Phosphoric Storage	1

Table 32.1 Major Equipment Summary - continued

Type of Equipment: Heat Exchangers

Equipment No.	Equipment Description	Number Required
38-E-101	Feed Preheater	2
38-E-102	Sour Water Stripper R/B	6
38-E-103	Stripped Water Cooler	6
38-E-104	Lean Solution Cooler	2
38-E-105	Absorber Quench Cooler	14
38-E-106	Solution Exchanger	4
38-E-107	Stripper Reboiler	4
38-E-108	Stripper Condenser	10
38-E-109	Fractionator Reboiler	1
38-E-110	Fractionator Condenser	10
38-E-111	Stripped Water Trim Cooler	4

Table 32.1 Major Equipment Summary - continued

Type of Equipment: Pumps		
Equipment No.	Equipment Description	Number Required
38-G-101	Stripped Water Pumps	2
38-G-102	Absorber Circulating Pumps	2
38-G-103	Quench Circulating Pumps	2
38-G-104	Rich Solution Pumps	2
38-G-105	Fractionator Feed Pumps	2
38-G-106	Fractionator R/F Pumps	2
38-G-107	Phos Acid Addition Pump	1

32.2 Catalyst and Chemical Summary

Catalyst and chemicals required for this plant are shown below:

Catalyst or Chemical	Phosphoric Acid as 100% H_3PO_4
Quantity required for start up	113,331 lb
Consumption	3,460 lb/day

32.3 On-Stream Factor

The expected on-stream factor for the PHOSAM-W Ammonia Recovery Unit is expected to be 96.4%

32.4 Operating Manpower Requirements

The operating manpower requirement for this plant as well as for Phenol Recovery Plant (Plant 39) is 20 operators. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

32.5 Plot Area Required

The plot area required for the Ammonia Recovery Unit is approximately 100 feet by 200 feet.

32.6 Capital Cost and Breakdowns

The field costs and breakdowns for Plant 38 are given below in Table 32.2. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41. Because there is no spare train for the first plant, the cost numbers, as shown in Table 32.2 below, for the first plant and Nth plant are the same.

TABLE 32.2

Plant 38 (Ammonia Recovery)
Field Costs and Breakdowns
2nd Quarter, 1991

Field Costs	**Costs ($MM)**	
Breakdowns	First Plant	Nth Plant
Major Equipment	12.4	12.4
Bulk Materials	9.9	9.9
Subcontracts	1.3	1.3
Direct Labor	8.7	8.7
Distributables (Indirect)	7.8	7.8
Total Field Costs	**40.1**	**40.1**

PLANT 39

33. Plant 39 (Phenol Recovery)

33.0 Design Basis, Criteria and Considerations

Ammonia Recovery (Plant 38) and Phenol Recovery (Plant 39) are closely related and together constitute the Project Sour Water Stripping, with the purpose of minimizing both raw water consumption and effluent discharge to public waters during normal plant operation. Sour water streams are segregated and treated as necessary to make them suitable for reuse, if practical, in lieu of fresh water.

Sour Water Treating

Dephenolization is a process technology development of LTV Corporation, licensed by the Packaged Plants Division of Glitsch Inc., for phenols recovery from sour water. This is accomplished by means of liquid-liquid extraction, in which the phenols are recovered as a salable product consisting of phenol and its homologs, cresols and xylenols. The phenols are extracted from the sour water with an organic solvent. The solvent is recovered by fractionation from the extracted phenols.

Design Basis

The capacity of the Dephenolization unit is 2,650 GPM of stripped sour water from the Ammonia Recovery Unit (plant 38). This allows approximately 10 percent spare capacity to permit work-off of sour water produced during non scheduled shutdowns. This unit recovers 31.3 TPSD of phenols. Dephenolated water goes preferentially to the Coal Liquefaction (Plant 2) as wash water. The rest goes to the Sewage and Effluent Treatment (Plant 34) where it is treated by Pac/Biological treatment to remove the organics. It is then clarified and filtered before going to the cooling tower as make-up. The yields are based on the Breckinridge Initial Effort plant and have been reviewed by the licensor and deemed as reasonable.

33.1 Major Equipment List

The equipment summary for the Phenol Recovery Unit is shown in Table 33.1.

33.2 Catalyst and Chemical Summary

Catalyst and chemicals required for this plant is shown below:

Catalyst or Chemical	Dephenolization Solvent
Quantity required for start up	7,912 lb
Consumption	170 lb/day

Table 33.1 Major Equipment Summary

Type of Equipment: Columns and Drums

Equipment No.	Equipment Description	Number Required
39-C-101	Saturation Column	1
39-C-102	Extractor	2
39-C-103	Raffinate Separator	2
39-C-104	Extract Separator	1
39-C-105	Slop Drum	1
39-C-106	Solvent Stripper	1
39-C-107	Solvent Distillation Column	1
39-C-108	Reflux Drum	1
39-C-109	Compressor Suction Drum	1
39-C-110	Solvent Recovery Scrubber	1
39-C-111	Solvent Separator	1
39-C-112	Phenol Column	1
39-C-113	Crude Phenol Drum	1
39-C-114	Solvent/Phenol Mix Drum	1
39-C-122	Solvent Drum	1

Table 33.1 Major Equipm nt Summary - continued

Type of Equipment: Heat Exchangers

Equipment No.	Equipment Description	Number Required
39-E-101	Raffinate Heater	1
39-E-102	Solvent Dist Column OVHD Cond	6
39-E-103	Solvent Dist Column Reboiler	2
39-E-104	Phenol Cooler	1
39-E-105	Phenol Column OVHD Cond	1
39-E-106	Phenol Column Reboiler	1
39-E-118	Wastewater Cooler/Heater	2

Type of Equipment: Pumps

Equipment No.	Equipment Description	Number Required
39-G-101	Raffinate Pump	2
39-G-102	Slop Pump	2
39-G-103	Extract Pump	2
39-G-104	Sour Water Pump	2
39-G-105	Solvent Reflux Pump	2
39-G-106	Solvent/Phenol Pump	2
39-G-107	Crude Phenol Pump	2
39-G-117	Solvent Make-up Pump	2

Type of Equipment: Compressors

Equipment No.	Equipment Description	Number Required
39-K-101	Stripping Gas Compressor	1

33.3 On-Stream Factor

The expected on-stream factor for the PHOSAM-W Ammonia Recovery Unit is expected to be 96.4%

33.4 Operating Manpower Requirements

The Ammonia Recovery (Plant 38) and Phenol Recovery (Plant 39) are expected to be operated using common operators. Thus the operators included in Plant 38, are required for both plants. For full manpower requirements of this plant as well as the complex, refer to Section 40 of this report.

33.5 Plot Area Required

The plot area required for the Phenol Recovery Unit is approximately 100 feet by 100 feet.

33.6 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 39 are given below in Table 33.2. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41. Because there is no spare train for the first plant, the cost numbers, as shown in Table 33.2 below, for the first plant and Nth plant are the same.

TABLE 33.2

Plant 39 (Phenol Recovery)
Field Costs and Breakdowns
2nd Quarter, 1991

Field Costs	**Costs ($MM)**	
Breakdowns	First Plant	Nth Plant
Major Equipment	3.5	3.5
Bulk Materials	3.7	3.7
Subcontracts	0.2	0.2
Direct Labor	3.1	3.1
Distributables (Indirect)	2.8	2.8
Total Field Costs	**13.3**	**13.3**

PLANT 40

34. Plant 40 (General Site Preparation)

34.0 Design Basis, Criteria and Considerations

The site is located in Southern Illinois with rail and road accessibility. The plant shall be built on a green field location, which will have to be made suitable for the purposes of building an industrial facility.

The preparation of the site involves the leveling of the approximately three square mile area, the addition of basic improvements such as roads fencing and drainage needed by the plant as a whole, and the placement of high load-bearing fills, pilings, spread footings and mat foundations for the plant structures in accordance with individual needs.

The general site is graded to a basic elevation of 650 feet above mean sea level (MSL) and the coal storage area is graded to 655 MSL. Most of the overburden removed in this operation is of low strength soil unsuitable for structural fill. It is stockpiled for to other uses.

Drainage of contaminated rain runoff from process and offplot areas is directed to ponds for treatment needed before plant usage. Uncontaminated storm runoff from building roofs, parking lots, outdoor storage areas and uncontaminated process plant areas is routed to the raw water storage pond.

34.1 Capital Cost and Breakdowns

The field costs and breakdowns for Plant 40 are given below in Table 34.1. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 34.1

Plant 40 (General Site Preparation)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	--
Bulk Materials	--
Subcontracts	75.0
Direct Labor	--
Distributables (Indirect)	--
Total Field Costs	**75.0**

PLANT 41

35. Plant 41 (Buildings)

35.0 Design Basis, Criteria and Considerations

Five types of buildings are provided for different usages. The type of construction selected for each building is dependent on its location with respect to potential hazards, its criticality for plant operation and its function.

In addition to general good practice, the designs of the buildings include the incorporation of the recommendations or requirements of the following:

- Occupational Safety and Health Administration (OSHA)
- State of Illinois Codes

  Oil Insurance Association (OIA) Publication 101, Hydrorefining Process Units
- National Electrical Code

The five types of buildings are classified as types A, B, C, D or Administrative according to their major construction features. The types and their construction features are shown below.

Type A

Type A buildings house critical equipment and/or instrumentation for the continuous operation of the plant.

The structures are blast-proof. 3 to 3-1/2 psig design, in accordance with OIA, with air lock entrances and exits. Buildings are pressurized to 0.1 to 0.2 inches of water.

The supporting structure is steel framed with concrete walls on the outside. Bearing walls and steel columns support the roof framing of steel beams and decking. Structural parts are fireproofed with three-hour-rated materials.

Interior walls are plaster boards on metal studs or are concrete block. Ceilings are installed in all rooms except mechanical equipment rooms.

Buildings are provided with heating, air conditioning, lighting, glazing, hardware, carpeting, electrical, plumbing, and sanitary systems.

Type B

Type B buildings are the plant laboratory, the cafeterias, the medical building, and the change house.

The supporting structure is steel framed with masonry walls. Loadbearing walls and steel columns support the roof framing of steel beams and decking. Structural parts are fireproofed with three-hour-rated materials.

Interior walls are plaster boards on metal studs or are concrete block. Ceilings are installed in all rooms except mechanical equipment rooms.

Buildings are provided with heating, air conditioning, lighting, glazing, hardware, carpeting, electrical, plumbing, and sanitary systems.

Type C

Type C buildings serve a number of diverse functions which are generally plant operations or maintenance related. These buildings are steel-framed structures sheathed and roofed with prefabricated-building-type metal panels.

The structure is of rigid steel frame with steel-trussed roof frame of self-framing metal panels. Where required, the building frame is designed for the support of cranes and monorails. Roof and wall sheathing is factory finished. Compressor shelters have partial side covering only. Metal sandwich panels are used where buildings require insulation.

Office areas are heated and air conditioned with package units.

Buildings are provided with lighting, hardware, glazing, painting, electrical and plumbing systems. Sanitary facilities are provided only in those buildings in which they are required.

Type D

Type D buildings are for the transformer shelters and chemical storage. They have masonry walls and structural steel-framed roofs with decking cover.

Interior partitions and walls are concrete block. No finished ceilings are required.

Buildings are provided with lighting, hardware, glazing, painting, electrical and plumbing systems. Sanitary facilities are provided only in those buildings in which they are required.

Administrative

The Administration Building (which also contains the computer room) is identical in construction to that of type B buildings except that the exterior is finished with brick veneer masonry.

Fire Protection

All buildings have portable fire extinguishers. Some have hand-held extinguishers and others have these plus wheeled portable extinguishers in accordance with OSHA standards.

The laboratories and the computer room are protected by halogen-type extinguishing systems. Personnel alarms are provided for protection in buildings and halogen-type extinguishing systems. Water sprinkler systems are provided where applicable.

Fireproofing of structural members in building types A and B is in accordance with Specification 14222-N-6. For additional information on fire protection refer to Fire Systems (Plant 33).

Utilities and Other Services

Drinking water, compressed air and steam are provided where required. Gas is provided to the laboratories. Electric power is provided for general lighting, convenience outlets and air conditioning. Connected load for air conditioning of buildings and control rooms is estimated at 500 KW.

Telephones are provided as shown in Telecommunication Systems (Plant 42).

One ambulance is provided for the medical building and fire trucks for the fire station in Mobile Equipment (Plant 33).

35.2 Building List

Table 35.1 lists all buildings by name or function and shows the building type, linear dimensions, area and quantity.

Table 35.1 - Building List

DESCRIPTION	NUMBER REQUIRED	SIZE (FT)	AREA (FT^2)	TYPE
Distributed System Control Room				
Coal Liquefaction	1	70 x 70	4,900	A
Hydrotreaters & Gas Plant	1	70 x 70	4,900	A
By-products & waste water	1	50 x 70	3,500	A
Boiler Plant	1	50 x 70	3,500	A
Operating Equipment Rooms				
Tank Farm	1	20 x 26	520	A
Process Plants	15	20 x 26	7,820	A
Plant Laboratory	1	100 x 200	20,000	B
Change House (Clean and Dirty Laundry)	1	100 x 200	20,000	B
Cafeteria	1	100 x 200	20,000	B
Cafeteria	1	50 x 100	5,000	B
Medical	1	50 x 100	5,000	B
Ash Handling	1	80 x 150	12,000	C
Operator Shelters				
Coal Pile	2	10 x 20	400	C
Solid Waste Disposal	1	10 x 20	200	C
Cooling Water Tower	1	10 x 20	200	C
Water Pond	1	10 x 20	200	C
Tank Car Loading	1	10 x 20	200	C

DESCRIPTION	NUMBER REQUIRED	SIZE (FT)	AREA (FT^2)	TYPE
Tank Truck Loading	1	10 x 20	200	C
Gate Houses	3	20 x 20	1,200	C
Guard/Security	1	50 x 100	5,000	C
Switchgear Buildings				
34.5 kV	2	100 X 30	6,000	C
13.8 kV	2	100 X 30	6,000	C
Process Plant	17	30 x 30	15,300	C
Fire Station	1	60 x 80	4,800	C
Warehouse	1	200 x 400	80,000	C
Maintenance Buildings				
B-1	1	100 x 200	20,000	C
B-2	1	40 x 100	4,000	C
B-3	1	60 x 100	6,000	C
B-4	1	40 x 100	4,000	C
B-5	1	100 x 100	10,000	C
B-6	1	40 x 100	4,000	C
Garages				
Mobile Equipment	1	40 x 100	4,000	C
General	1	100 x 100	10,000	C
Compressor Shelters				
Plant 1.4 Roller Mill Shelters	5	20 x 20	2,000	C
Plant 2	6	30 x 100	18,000	C
Plant 4	2	60 x 90	10,800	C
Plant 5	2	50 x 90	5,000	C
Plant 6	15	30 x 40	18,000	C

DESCRIPTION	NUMBER REQUIRED	SIZE (FT)	AREA (FT^2)	TYPE
Plant 10 (Air Blowers)	10	20 x 40	8,000	C
Plant 10	5	30 x 90	13,500	C
Pumps, Chemical Feed, Filter Shelters	15	20 x 30	9,000	C
Transformer Houses	4	50 x 26	5,200	C
Special Cleaning, Foam Chemicals	1	30 x 40	1,200	D
Administration Building	1	200 x 300	120,000 (2-story)	D

35.3 Control Systems List

The overall concept for the Distributed Control System (DCS) and operator interface is to have one central control room, except for shipping and loading facilities. The central control room will have five operator consoles, one for each area, the supervisory computer and a DCS engineering console. Each area console will have three double stacked operator stations for each board operator expected to be assigned to each console plus three added operator stations and two printers. The central control building will also contain the racks for the controllers and Input/Output (I/O) serving process equipment located near the central control building.

The Shipping and Loading control building will contain all the controllers, I/O and operator interfaces serving the shipping and loading facilities.

Each of the four satellite buildings will contain the controllers and I/O for the process equipment surrounding each building. Each satellite will also contain one operator station for process information display to the field operators.

The Honeywell DCS has been scoped to have a separate Logic Control Network (LCN) highway system for each of the five areas. The sizing of the DCS equipment and redundancy philosophy are the same as used on previous estimates. The redundant Process Manager (PM)controllers are sized to each handle 50 control valves. The redundant PM modules control I/O, and thermocouple multiplexer cards for non-control thermocouples.

The overall I/O summary list by area of the plant is shown in Table 35.2. The individual area TDC 3000 requirements for areas 1 through 5 are shown in Tables 35.3 through 35.7. The engineering, computing and maintenance TDC 3000 requirements are shown in Table 35.8.

TABLE 35-2
I/O SUMMARY BY AREA

Plant	Units Controlled	Total	DI	DO	HLAI	LLAI	AO	Equiv. No. CV's	Board Opers.	Oper. Sta.	Trains	Avg. Wiring Dist. (ft.)
1	Coal Cleaning	120	120	0	0	0	0	0			6	3000
1.4	Grind & Dry	1020	480	360	0	120	60	60			12	2000
9	Gasification	7110	1778	1208	1635	1778	711	711			7	700
10	Air Sep.	850	212	144	196	213	85	85			5	400
Total	**Area 1**	**9100**						**856**	**6**	**20**		
2	Coal Liquefaction	5280	1320	898	1214	1320	528	528			6	1200
8.1	Solvent Deashing	240	60	41	55	60	24	24			1	400
Total	**Area 2**	**5520**						**552**	**4**	**14**		
3	Gas Plant	980	245	167	225	245	98	98			2	1000
4	Naphtha HTU	640	160	109	147	160	64	64			2	1000
5	Gas Oil HTU	1280	320	218	294	320	128	128			2	600
6	Hydrogen Purif.	1680	420	286	386	420	168	168			2	600
11	Sulfur Recvry.	2400	600	408	552	600	240	240			5	700
38	Ammonia Remvl.	540	135	92	124	135	54	54			1	600
39	Phenol Remvl.	670	168	114	154	167	67	67			1	1000
Total	**Area 3**	**8190**						**819**	**5**	**18**		
19	Flare	30	8	5	7	7	3	3			1	5000
20	Storage Tanks	420	105	71	97	105	42	42			32 Tank	4000
22	Shipping	20	5	3	5	5	2	2			1	500
25	Catalyst Hdlg.	-----									1	-----
34	Wastewater	680	170	116	156	170	68	68			1	1800
24	Solid Waste	-----									1	-----
23	Loading	84	36	24	12	12	0	0			6RR. 6TR	2000
Total	**Area 4**	**1234**						**115**	**2**	**6**		
30	Elect. Dist.	12	12	0	0	0	0	0			6 CNTRS	500
31	Steam & Power	2583	1480	75	469	469	90	90			5 GT. 2S	800
32	H2O System	345	150	150	15	15	15	15				5000
33	Fire Protect.	54	15	10	14	15	0	0			3 Loops	1000
35	Inst. & Plant Air	30	7	5	7	8	3	3				800
Total	**Area 5**	**3024**						**108**	**2**	**5**		
41	Buildings	66	60	0	6	0	0	0				
Grand Totals		27134	8066	4504	5770	6344	2450	2450	19	72		

Operator stations include 3 for engineering and 5 remote stations

Table 35-3 HONEYWELL TDC 3000 REQUIREMENTS – AREA 1	
Quantity	**Description of Equipment**
20	Double-stacked Universal Stations with station electronics, touchscreens, operator keyboards, one engineer's keyboard
1	Remote Universal station with touchscreens, operator keyboard, and station electronics
2	Work surfaces
2	Floppy drives
2	Bernoulli drives
4	WREN III History Modules
1	Application Module
1	Computer Module
1	PLC Gateways/Hiway Gateway (redundant)
2	PLC Gateway/Hiway Gateway (non-redundant for OEM packages)
4	Network Interface Modules, redundant
19	Redundant Process Managers with I/O cabinets and FTA cards computer communications software
	LCN Cable
	UCN Cable
	UCN Cable extenders
1	Flagstaff Engineering Drive
2	ASPI 46 printers
1	Logic system (PLC's, CPC's)

Table 35-4 HONEYWELL TDC 3000 REQUIREMENTS – AREA 2	
Quantity	**Description of Equipment**
14	Double-stacked Universal Stations with station electronics, touchscreens, operator keyboards, one engineer's keyboard
1	Remote Universal station with touchscreens, operator keyboard, and station electronics
2	Work surfaces
2	Floppy drives
2	Bernoulli drives
2	WREN III History Modules
1	Application Module
1	Computer Module
1	PLC Gateways/Hiway Gateway (redundant)
1	PLC Gateway/Hiway Gateway (non-redundant for OEM packages)
3	Network Interface Modules, redundant
11	Redundant Process Managers with I/O cabinets and FTA cards computer communications software
	LCN Cable
	UCN Cable
	UCN Cable extenders
1	Flagstaff Engineering Drive
2	ASPI 46 printers
1	Logic system (PLC's, CPC's)

Table 35-5
HONEYWELL TDC 3000 REQUIREMENTS – AREA 3

Quantity	Description of Equipment
18	Double-stacked Universal Stations with station electronics, touchscreens, operator keyboards, one engineer's keyboard
1	Remote Universal station with touchscreens, operator keyboard, and station electronics
2	Work surfaces
2	Floppy drives
2	Bernoulli drives
6	WREN III History Modules
1	Application Module
1	Computer Module
1	PLC Gateways/Hiway Gateway (redundant)
2	PLC Gateway/Hiway Gateway (non-redundant for OEM packages)
4	Network Interface Modules, redundant
17	Redundant Process Managers with I/O cabinets and FTA cards computer communications software
	LCN Cable
	UCN Cable
	UCN Cable extenders
1	Flagstaff Engineering Drive
2	ASPI 46 printers
1	Logic system (PLC's, CPC's)

Table 35-6
HONEYWELL TDC 3000 REQUIREMENTS – AREA 4

Quantity	Description of Equipment
6	Double-stacked Universal Stations with station electronics, touchscreens, operator keyboards, one engineer's keyboard
1	Remote Universal station with touchscreens, operator keyboard, and station electronics
2	Work surfaces
2	Floppy drives
2	Bernoulli drives
1	WREN III History Modules
1	Application Module
1	Computer Module
1	PLC Gateways/Hiway Gateway (redundant)
1	PLC Gateway/Hiway Gateway (non-redundant for OEM packages)
1	Network Interface Modules, redundant
3	Redundant Process Managers with I/O cabinets and FTA cards computer communications software
	LCN Cable
	UCN Cable
	UCN Cable extenders
1	Flagstaff Engineering Drive
2	ASPI 46 printers
1	Logic system (PLC's, CPC's)

Table 35-7
HONEYWELL TDC 3000 REQUIREMENTS – AREA 5

Quantity	Description of Equipment
6	Double-stacked Universal Stations with station electronics, touchscreens, operator keyboards, one engineer's keyboard
1	Remote Universal station with touchscreens, operator keyboard, and station electronics
2	Work surfaces
2	Floppy drives
2	Bernoulli drives
1	WREN III History Modules
1	Application Module
1	Computer Module
1	PLC Gateways/Hiway Gateway (redundant)
1	PLC Gateway/Hiway Gateway (non-redundant for OEM packages)
1	Network Interface Modules, redundant
3	Redundant Process Managers with I/O cabinets and FTA cards computer communications software
	LCN Cable
	UCN Cable
	UCN Cable extenders
1	Flagstaff Engineering Drive
2	ASPI 46 printers
1	Logic system (PLC's, CPC's)

Table 35-8
TDC 3000 REQUIREMENTS -- ENGINEERING, COMPUTING & MAINTENANCE

Quantity	Description of Equipment
3	Universal Stations with station electronics, touchscreens, engineer and operator keyboards
2	Work surfaces
2	Floppy drives
2	Bernoulli drives
1	WREN III History Modules
1	Application Module
1	Computer Module
1	PLC Gateways
1	Network Interface Modules, redundant
1	Midrange DEC/VAX computer
2	VAX workstations
2	VAX highspeed printers
	Computer communications software
1	ASPI 46 Printers

35.3 Capital Cost and Breakdowns (First & Nth Plant)

The field costs and breakdowns for Plant 41 are given below in Table 35.9. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 35.9

Plant 41 (Buildings/DCS System)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	--
Bulk Materials	24.5
Subcontracts	46.0
Direct Labor	--
Distributables (Indirect)	--
Total Field Costs	**70.5**

PLANT 42

36. Plant 42 (Telecommunications Systems)

36.0 Design Basis, Criteria and Considerations

Plant 42, in serving the telecommunications requirements for the initial phases of mobilization and construction, is designed with sufficient flexibility to allow for conversion to final plant operation.

Master communications central control and monitoring of all subsystems are provided for the plant operation phase.

Reliability, a prime factor in the design of the plant, is achieved through the use of solid-state components, factory burn-in of assemblies, redundant assemblies, alternative traffic flow routing and, where possible, automatic operation.

Maintainability is achieved through modular organization of hardware assemblies, automatic fault detection and alarm systems, standardization of components and procurement sources and a spare inventory based upon mean-time-between-failure (MTBF) data and repair cycle time.

Flexibility is achieved through the usage of central electronic switching, shelterized (transportable) facilities, commonality of subassemblies where possible and a system capacity adequate for all three phases of the development.

36.1 Equipment List

Table 36.1 summarizes by plant operational phase the telecommunications equipment and/or systems installed. Each system also is further described in the following pages.

TABLE 36.1

TELECOMMUNICATIONS INSTALLATION

TELECOMMUNICATION TYPE OR SYSTEM	MOBIL-IZATION	CONSTRUC-TION	OPERA-TION
Battery Plant		X	X
Cable plant, outside (for interconnection, grounding, etc.)		X	X
Computer remote access terminal	X	X	X
Facsimile	X	X	X
Fire alarm and public address paging system, administration building			X
Medical life-signs telemetry		X	X
Paging, intraplant party			X
Radio, land mobile, local	X	X	X
Radio, land mobile, radio telephone		X	X
Radio, land mobile to railroad operations		X	X
Radio, maritime mobile		X	X
Radio, paging		X	X
Security system		X	X
Telephone (before plant completion, locally available services are used during the mobilization phase)	X	X	X
Telephone PABX		X	X

36.2 Capital Costs and Breakd wns (First & Nth Plant)

The field costs and breakdowns for Plant 42 are given below in Table 36.2. This plant being an OSBL plant, its field costs and breakdowns are the same for the first as well as the Nth plant scenarios. Note that the field costs for each plant do not include home office costs or contingency. These were estimated for the whole complex and are given in Section 41.

TABLE 36.2

Plant 42 (Telecommunications Systems)
Field Costs and Breakdowns
(First & Nth Plants)
2nd Quarter, 1991

Field Costs and Breakdowns	Costs ($MM)
Major Equipment	--
Bulk Materials	2.0
Subcontracts	--
Direct Labor	--
Distributables (Indirect)	--
Total Field Costs	**2.0**

OVERALL RAW MATERIAL, CATALYST AND CHEMICAL COSTS (BASELINE)

37. Overall Raw Material, Catalyst and Chemical Costs (Baseline)

Raw Material

The raw material for this plant is ROM coal. The amount of coal required for the entire complex is 29,036 TPSD (MF basis) and the unit cost is $20.50 (reference Coal Week, March 9, 1992).

Catalyst and Chemicals Costs

The catalyst and chemicals costs for the entire complex are presented in Table 37.1 below. As shown in this table, the costs are presented in two ways; 1) as a part of the variable operating costs, and 2) as a part of the fixed capital costs (initial catalysts and chemicals).

Table 37.1
CATALYSTS AND CHEMICALS COST

Plant Number	Description of Plant	Cost Thousand Dollars	
		(1)	(2)
1	Coal Cleaning and Handling	$406	$301
2	Coal Liquefaction Plant	$71,537	$24,643
3	Gas Plant	$26	$22
4	Naphtha Hydrotreater	$80	$260
5	Gas Oil Hydrotreater	$538	$1,752
6	Hydrogen Purification	$39	$199
8	Critical Solvent Deashing Unit	$89	$379
9	Hydrogen Production by Coal Gasification	$2,091	$6,750
10	Air Separation	$0	$0
11	By-Product Recovery	$803	$1,666
31	Steam and Power Generation	$96	$26
32	Raw Cooling and Potable Water Systems	$3,551	$951
34	Sewage and Effluent Water Treatment	$358	$94
38	Ammonia Recovery	$375	$128
39	Phenol Recovery	$30	$11
	Total	$80,021	$37,185

Note:
(1) Catalysts and chemicals cost per year as a part of variable operating costs
(2) Initial catalyst and chemicals cost as a part of capital costs

OVERALL PRODUCT/BYPRODUCT VALUES (BASELINE)

38. Overall Product/By-product Values (Baseline)

Product

The in-depth discussion on product values is included in Subsection 3.2 of Volume I of this report. The product valuations (expressed as syncrude premium) range from 1.06 to 1.27. The upper (1.27) and lower limits (1.07) will be utilized in the economics section.

The complex is designed to produce 61,943 BPSD of C5+ coal liquids.

By-product

	Production Rate	Price
Sulfur	740.4 STPD	$80/ton
Ammonia	243.7 STPD	$120/ton
Phenol	32.0 STPD	$400/ton
Propane	4407 BPSD	$7.50/bbl
Mixed Butanes	3541 BPSD	$14.50/bbl

OVERALL UTILITY UNIT PRICES AND CONSUMPTIONS (BASELINE)

39. Ov rall Utility Unit Prices and Consumptions (Baseline)

The overall utility unit prices were included in Section 3.1 and are reiterated below in Table 39.1

Table 39.1

Raw Material and Utility Pricing

Item	Cost
Feed Coal	20.50 [1] $/s. ton
Raw Water	0.10 [2] $/Mgal
Natural Gas	2.00 [3] $/MMBTU

(1) Coal Week, March 9, 1992
(2) Typical price for raw water in Southern Illinois
(3) General consensus between Amoco, Bechtel and DOE/PETC

The overall utility balance is shown in Table 39.2. As shown in this table, the utility requirements for the complex are:

Water:	1,899 gpm
Natural gas:	3,510 MM BTU/HR

Table 39.2

Overall Utility Balance

27-Nov-91

COAL LIQUEFACTION - BASE-LINE CASE

Plant No.	PLANT NAME	Fuel Gas MMbtu/hr	Electric Power KW	Steam Psig, Lb/hr 600 Sup @720 F	600 @489 F	150 @366 F	50 @298 F	Cond/BFW Net Cons lb/hr	Cooling Water gpm	Sour Water gpm	Waste Water gpm	Makeup Water gpm	Air scfm	Nitrogen scfm
	PROCESSING UNITS													
1	Coal Cleaning and Handling		8,289								785			
1.4	Coal Griding and Drying	486	12,114						240				5,956	75,063
2	Coal Liquefaction	1,090	58,988	5,565	(149,090)	(90,095)	56,115	424,715	8,095	(2,428)				715
3	Gas Plant	(1,473)	913		396,610		17,186	(413,796)	21,955	(5)				
4	Naphtha Hydrotreater	74	1,073		26,622			(26,622)	2,564	(40)		(38)		
5	Gas Oil Hydrotreater	162	2,179		65,048	(33,864)		(26,184)	8,228	(88)		(73)		
6	Hydrogen Purification		43,944				59,473	(59,473)	6,662	(70)		(60)		
8	Critical Solvent Deashing	212	4,363			25,419				(51)				
9	H2 Production by Coal Gasification	(981)	63,210		(291,800)	(762,900)	(781,300)	1,836,000	52,600	(966)	95	(1,196)		23,611
10	Air Seperation		159,994											(555,197)
11	By-product Sulfur Recovery	69	3,062		59,956	(186,541)	54,468	72,117	8,126	(123)				
ALL	Common Users			73000		40000	90000	(193,000)				(532)	9044	
	Sub Total (Process)	(361)	358,129	78,565	107,346	(1,007,981)	(504,058)	1,613,757	108,470	(3,771)	880	(1,899)	15,000	(455,808)
	OFFSITES													
19	Reli f and Blowdown		19											
20	Tankage		6,758			22,000	3,300	(25,300)	100					
30	Electrical Distribution													
31	Steam and Power Generation	3,871	(396,295)	(511,963)		381,996	436,191	(593,853)	65,667		(322)	(898)		
32	Raw, Cooling and Potable Water Systems		13,652						(255,529)		(1,011)	12,042		
33	Fire Protection		44											
34	Sewage & Effluent Treatment		7,313				3,000	(3,000)				(1,011)		
35	Instrument & Plant Air Systems		2,894										(15,000)	
36	Purge and Flish Oil System		258											
37	Solid Waste Disposal		48								90			
38	Ammonia Recovery		1,531		326,052	581,269		(907,321)	76,821	3,771				
39	Phenol Recovery		814			22,716	61,567	(84,283)	4,471		(1,033)			
Other	Bldg 41,42, Light, Etc.		4835											
	Natural Gas Imported	(3,510)												
	Off Site BL and Evapration										1,396	(8,234)		
	Sub Total (Offsite)	361	(358,129)	(511,963)	326,052	1,007,981	504,058	(1,613,757)	(108,470)	3,771	(880)	1,899	(15,000)	0
	GRAND TOTAL	0	0	(433,398)	433,398	0	0	0	0	0	0	0	0	(455,808)

OVERALL LABOR REQUIREMENTS AND RATES (BASELINE)

40. Overall Labor Requir ments and Rates (Baseline)

40.1 Staffing Plan

The overall staffing plan for the liquefaction complex is based on the following assumptions:

The complex is operated by a major oil company with support from corporate engineering

Process plants are divided into 5 areas with dedicated maintenance for each area

- Contract maintenance will be utilized during any plant turn-around and other non-routine maintenance

Complex is operated from one central house, except for shipping and loading

The staffing plan for the entire complex is shown in various figures. Figure 40.1 is the overall plant management chart. Figures 40.2 through 40.7 respectively present the organization chart and personnel for the 1) laboratory, 2) operations, 3) engineering, 4) environmental health, safety and security, 5) administration and 6) maintenance.

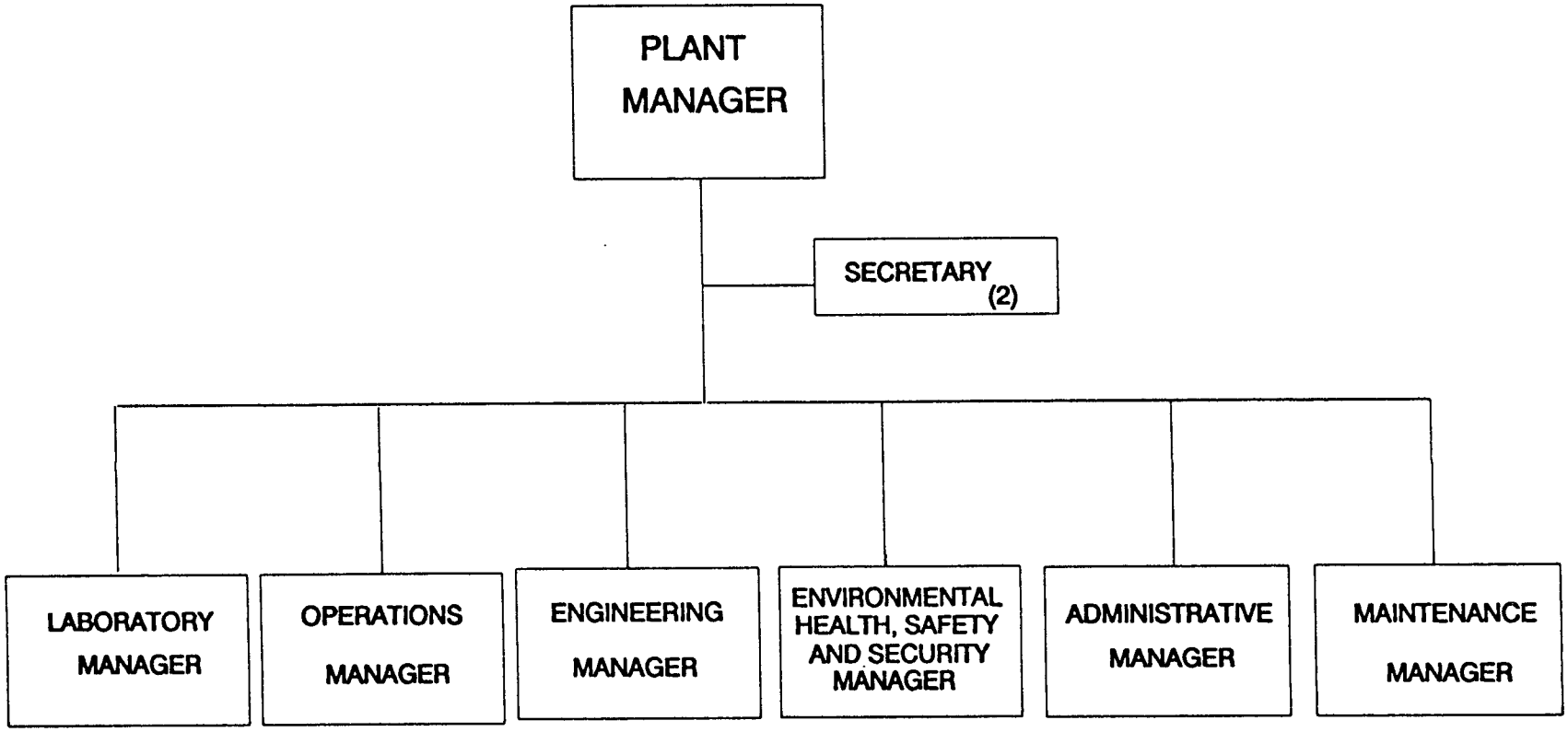

FIGURE 40.1

OVERALL PLANT ORGANIZATION

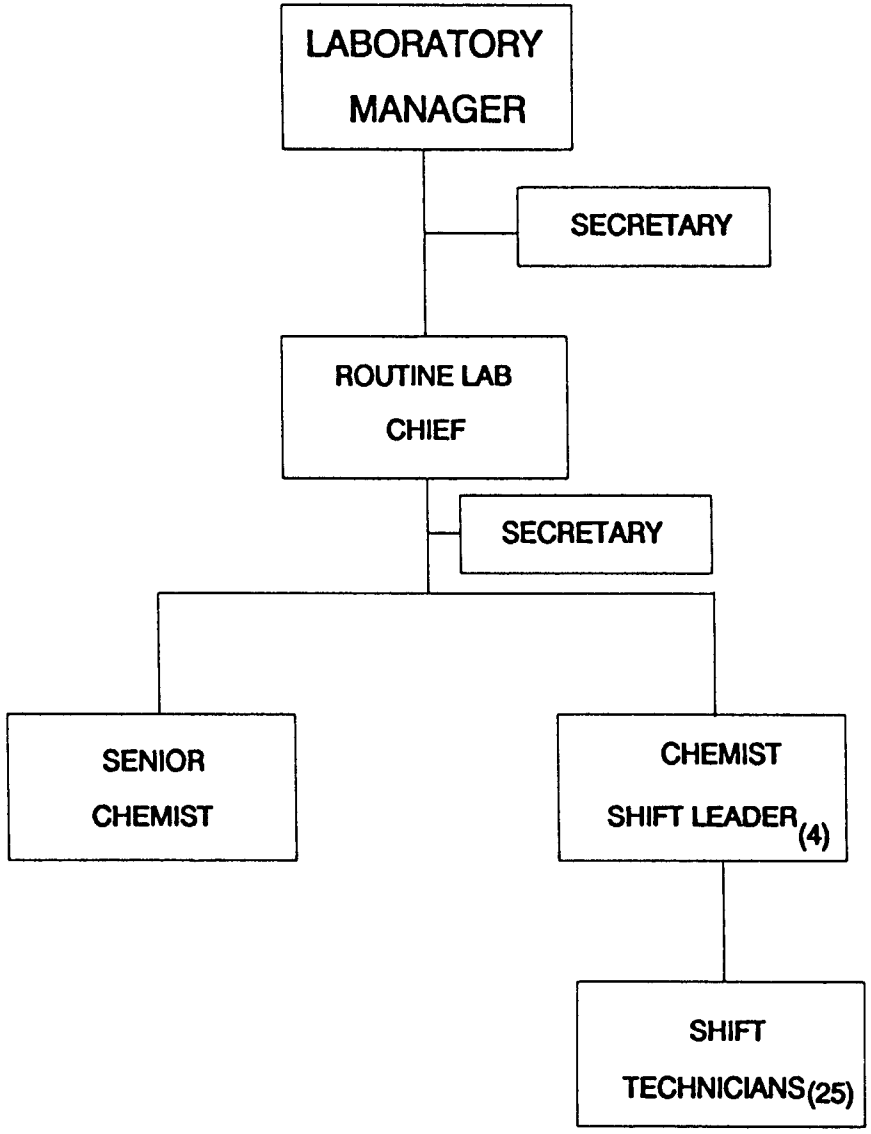

FIGURE 40.2
LABORATORY ORGANIZATION AND PERSONNEL

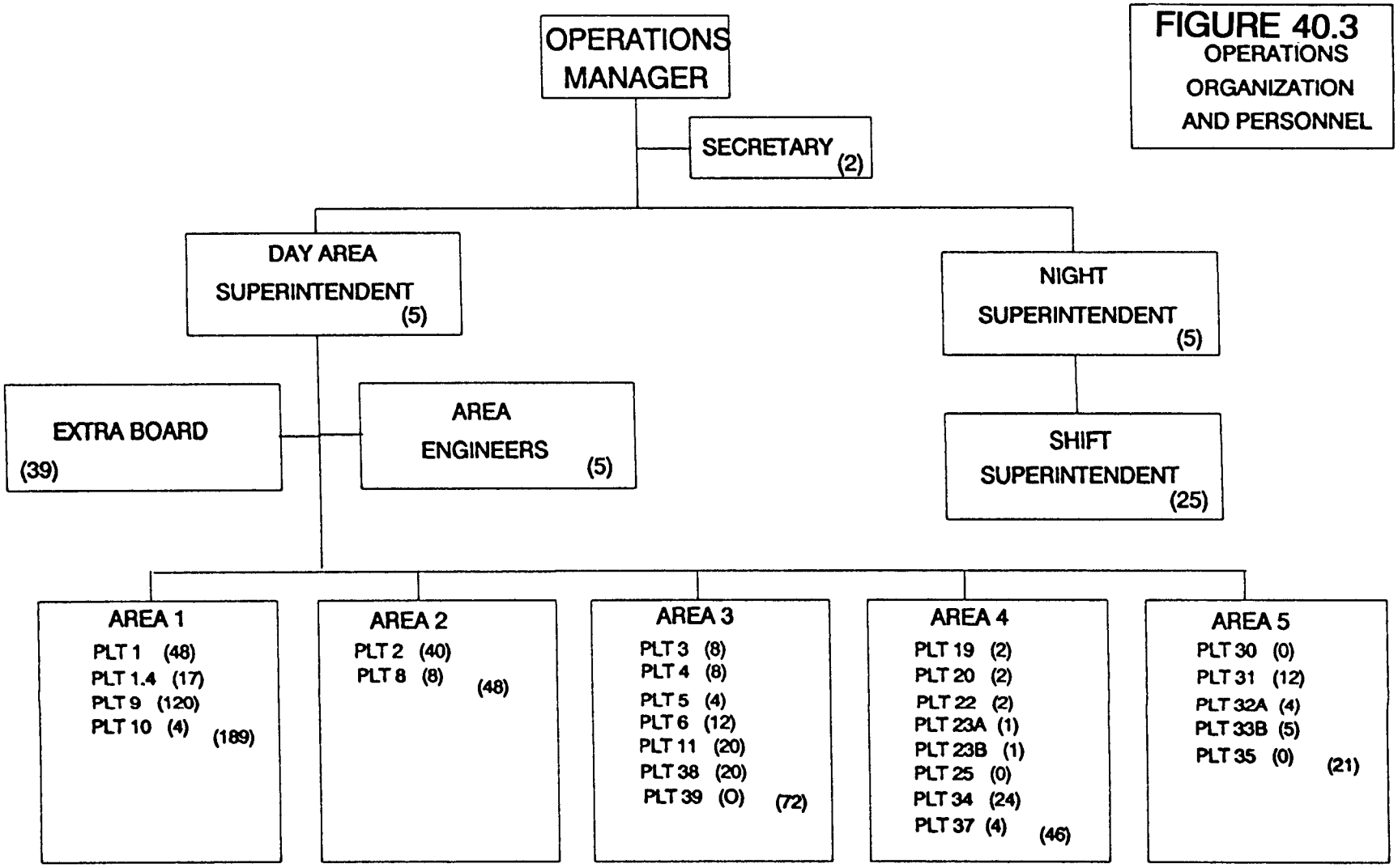

FIGURE 40.3
OPERATIONS ORGANIZATION AND PERSONNEL

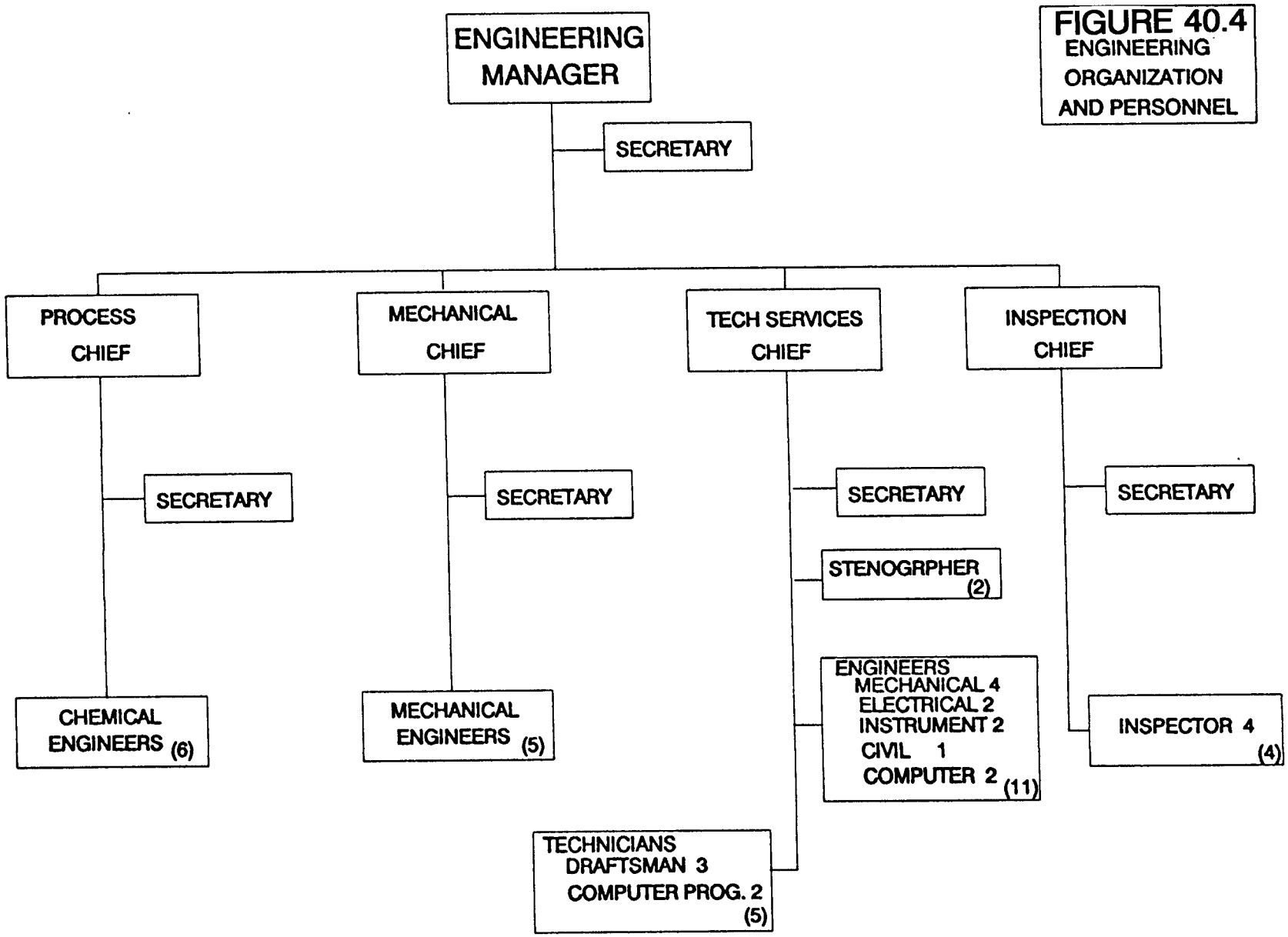

FIGURE 40.4
ENGINEERING ORGANIZATION AND PERSONNEL

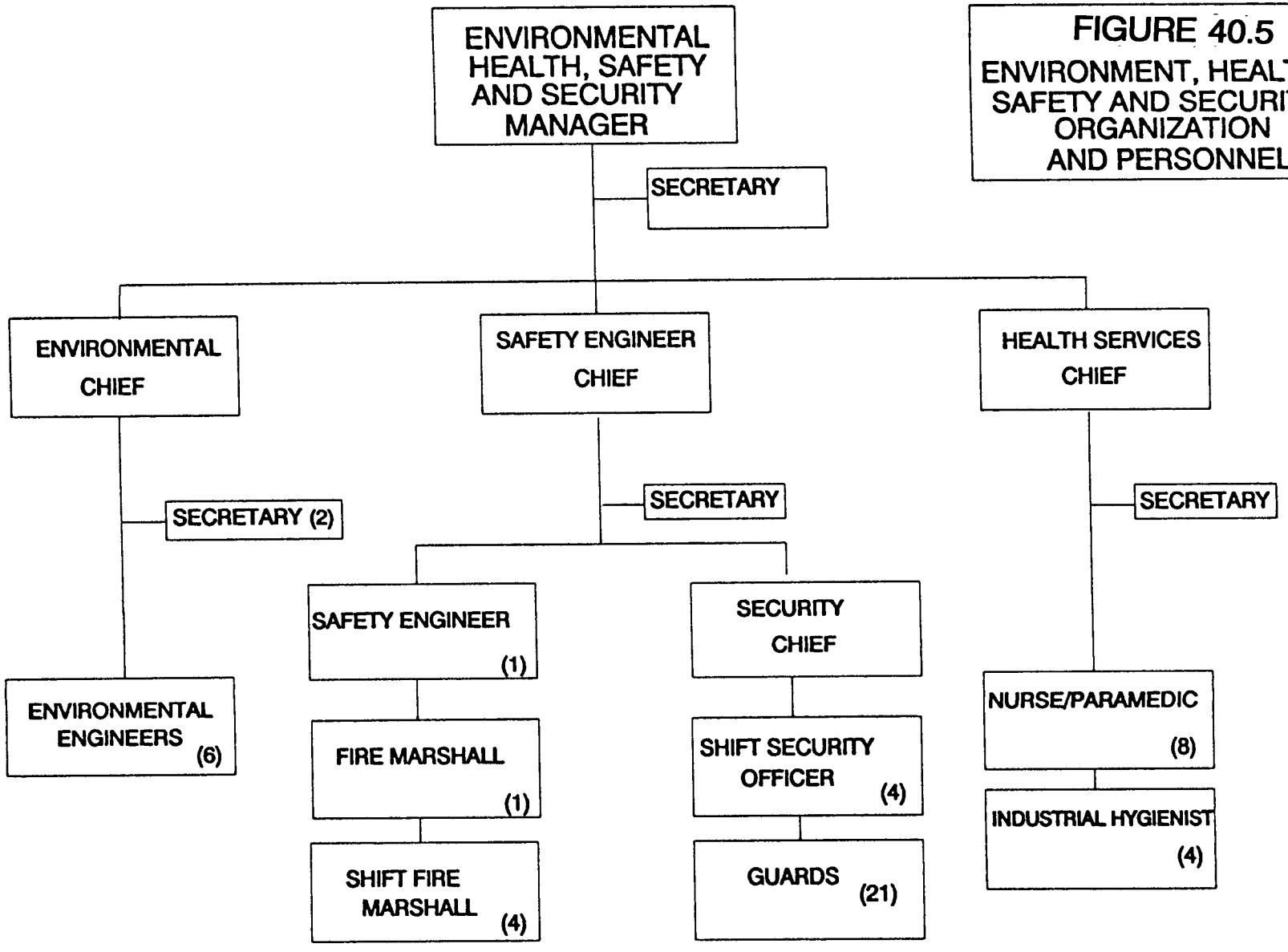

FIGURE 40.5
ENVIRONMENT, HEALTH, SAFETY AND SECURITY ORGANIZATION AND PERSONNEL

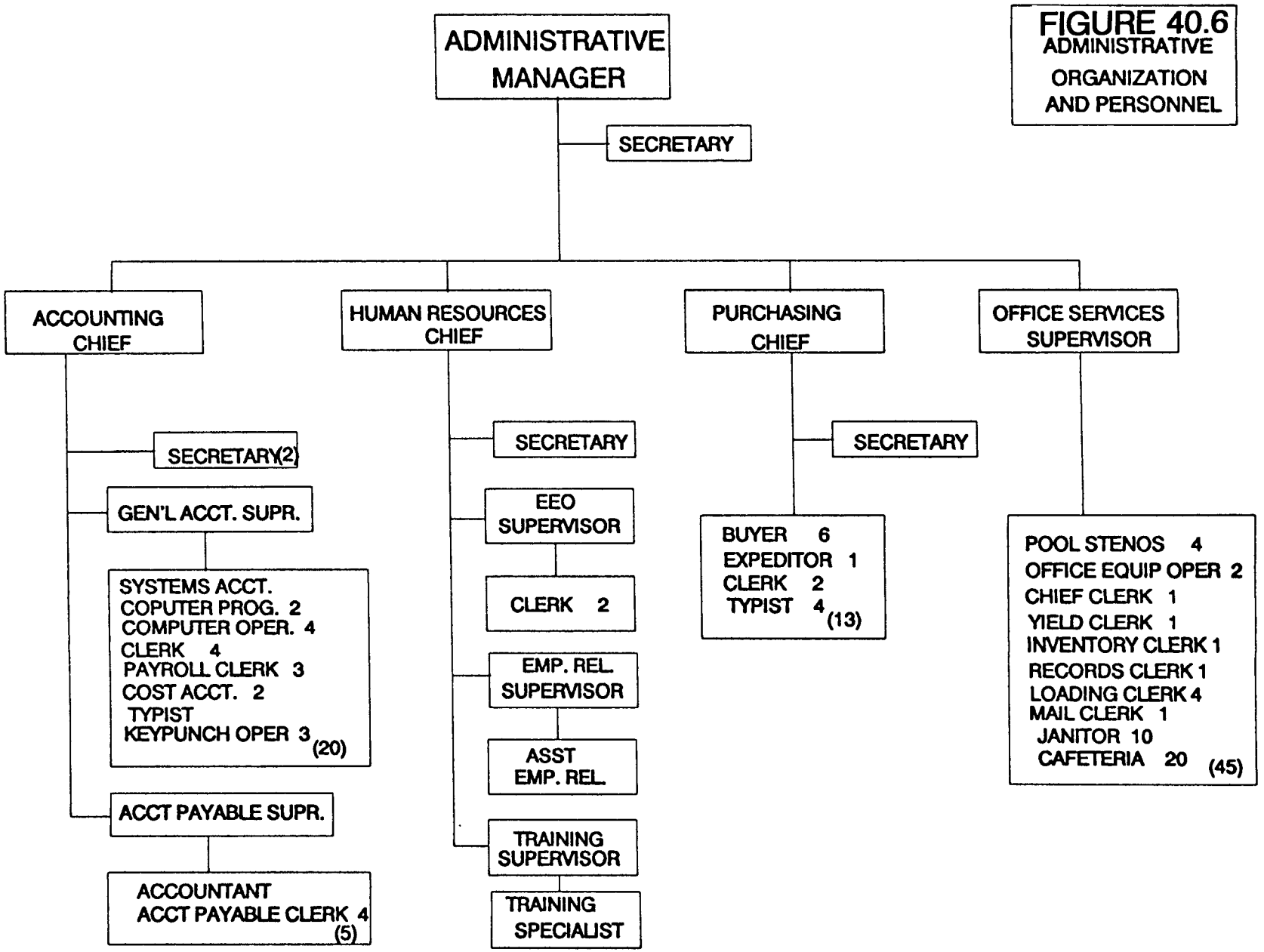

FIGURE 40.6
ADMINISTRATIVE ORGANIZATION AND PERSONNEL

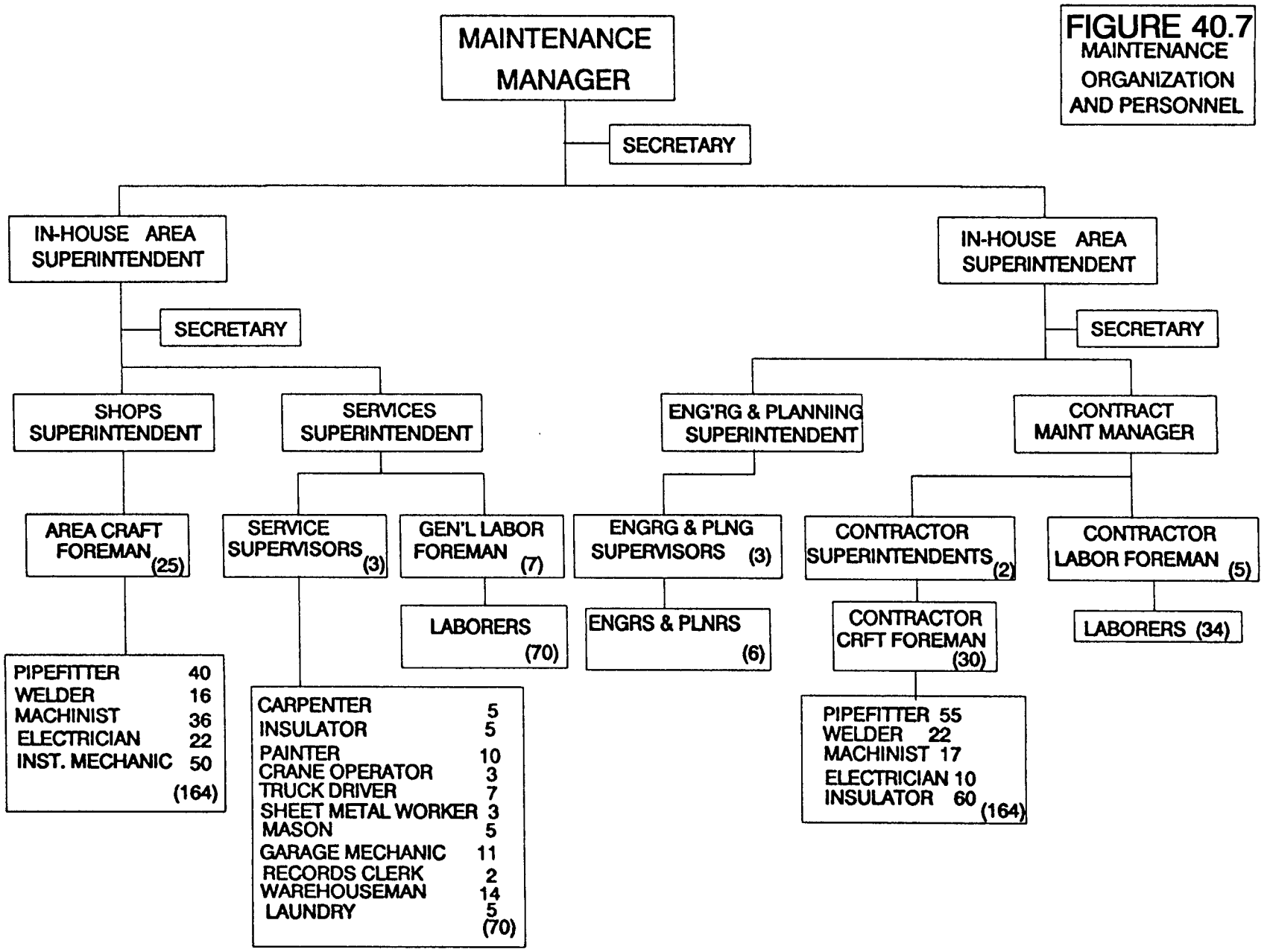

FIGURE 40.7
MAINTENANCE ORGANIZATION AND PERSONNEL

40.2 Base Wages and Salaries

The base wages and salaries that will be used in the economics section are included in Table 40.1 below.

Table 40.1

Base Wages and Salaries

Category	Annual Salary Dollars
Plant Manager	94,000
Functional Manager	83,000
Shift Leader (Engineers/Chemists)	72,000
Area Supervisor	64,000
Area Engineers	56,000
Engineers	49,600
Adm. Secretary (Plant Manager)	27,000
Adm. Secretary (Functional Manager)	24,000
Secretary	21,500
Crafts	**Hourly Rate Dollars**
Insulators	23.23
Painters	19.30
Plumbers & Gas Fitters	19.20
Sheet Metal Worker	18.55
Steam Fitters	21.59
Boilermakers	21.15
Carpenters	19.41
Electricians	22.17
Masons	19.65

FIRST PLANT OVERALL CAPITAL COSTS (BASELINE)

41. First Plant Ov rall Capital Costs (Baseline)

The First Plant overall capital cost estimates (baseline) for the entire complex are presented in this section. The estimate basis, methodology and accuracy are presented in Section 3.0 of Volume I of this report.

The inside battery limits (ISBL) and outside battery limits (OSBL) plant field costs and breakdowns are summarized in Sections 41.0 and 41.1 respectively. These same field costs and breakdowns are given in the appropriate capital cost sections of each plant throughout Volumes I and II of this report.

Section 41.2 presents the ISBL plants on installed basis. The ISBL installed basis costs includes the following costs:

- Field costs of ISBL plants
- Field costs of OSBL plants
- Home office costs and fees
- A suitable contingency

The above costs, when added together become the total installed cost of the complex. These costs (field costs of OSBL plants, Home office costs and fees and a suitable contingency) have been allocated to the ISBL plants. In this fashion, each ISBL plants cost can now be expressed on "Installed" basis. Such allocation of costs and the resulting installed costs for each plant and for the entire complex are shown in Table 41.2.

Section 41.3 presents the overall plant installed costs of Section 41.2 on an account-by account basis. Table 41.3 includes the overall Home office and fees as well as the contingencies estimated for the total complex.

Obviously, Sections 41.2 and 41.3 present the same bottom line overall installed cost of the complex in two different ways. This installed cost for the First Plant based on second quarter 1991 datum is $3871.7 million dollars. No project escalation is included in this figure for disbursement of this cost over the life of this project. Such escalation will be addressed in the economics section, Volume III, of this report.

41.0 ISBL Plant Fi ld Cost Summaries

The ISBL plant field costs for the entire complex are developed by estimating the field costs of each process plant. The field cost for each plant is comprised of 1) major equipment, 2) bulk materials, 3) subcontracts, 4) direct labor and 5) distributables. Cost data thus developed are shown in Table 41.0.

Table 41.0
Estimated Total Field Costs
for Coal Liquefaction Complex - Process Units (ISBL)
(2nd Quarter 1991 $Million)
First Plant

Plant No.	Process Units	Major Equipment	Bulk Materials	Sub-contracts	Direct Labor	Distribu-tables	Total Field Costs
1	Coal Handling	34.8	19.7	--	19.2	17.3	91.0
1.4	Coal Crushing	37.8	23.8	5.4	20.0	18.0	105.0
2	Coal Liquefaction	344.4	279.6	20.4	249.6	224.6	1118.6
3	Gas Plant	8.3	5.8	0.9	5.4	4.9	25.3
4	Naphtha Hydro.	5.2	3.5	0.5	3.4	3.0	15.6
5	Gas Oil Hydro.	24.8	16.9	2.7	15.6	14.0	74.0
6	H_2 Purification	61.0	31.0	3.6	30.0	27.0	152.6
8	ROSE Unit	13.0	10.0	4.0	8.0	7.2	42.2
9	H_2 From Coal	97.7	75.3	12.7	68.7	61.9	316.3
10	Air SEP	104.0	20.0	17.0	29.0	21.0	191.0
11	Sulfur Plant	15.2	10.4	1.8	10.2	9.1	46.7
38	NH3 Recovery	12.4	9.9	1.3	8.7	7.8	40.1
39	Phenol 11	3.5	3.7	0.2	3.1	2.8	13.3
	TOTALS	762.1	509.6	70.5	470.9	418.6	2231.7

Spare Plants = 2 spare plants for plant 1.4, 1 spare plant for plant 2 and 1 spare plant for plant 9

41.1 OSBL Plant Field Cost Summaries

The OSBL plant field costs for the entire complex are developed by estimating the field costs of each offsite/utilities plant. The field cost for each plant is comprised of 1) major equipment, 2) bulk materials, 3) subcontracts, 4) direct labor and 5) distributables. Results thus obtained are shown in Table 41.1.

Table 41.1

Estimated Total Field Costs
for Coal Liquefaction Complex - Offsites/Utilities (OSBL)
(2nd Quarter 1991 $Million)
First Plant

Plant No.	Offsite Units	Major Equipment	Bulk Materials	Sub-contracts	Direct Labor	Distribu-tables	Total Field Costs
19	Relief & Blowdown	2.0	1.5	0.1	1.4	1.3	6.3
20	Tankage	38.0	25.5	3.4	22.3	20.1	109.3
21	Interconn. Piping	--	23.5	4.0	22.5	20.3	70.3
22	Product Shipping	0.2	0.3	0.1	0.1	0.1	0.8
23	Tank Car/Truck	2.0	3.4	0.7	3.2	2.9	12.2
24	Ash Disposal	11.1	4.8	1.5	6.0	5.4	28.8
25	Catalyst & Chemicals	--	--	0.3	--	--	0.3
30	Electrical Distribution	--	41.0	--	18.0	16.2	75.2
31	Steam & Power	180.4	33.3	3.2	33.2	29.9	280.0
32	Water	17.5	7.5	4.9	6.8	6.1	42.8
	SUBTOTALS	251.2	140.8	18.2	113.5	102.3	626.0

Spare Plants = None

Table 41.1 - continued

Estimated Total Field Costs
for Coal Liquefaction Complex - Offsites/Utilities (OSBL)
(2nd Quarter 1991 $Million)
First Plant

Plant No.	Offsite Units	Major Equipment	Bulk Materials	Sub-contracts	Direct Labor	Distribu-tables	Total Field Costs
33	Fire Protection	2.7	5.3	0.2	7.5	6.8	22.5
34	Sewage	7.9	10.2	0.7	15.1	13.6	47.5
35	Instr/Plant Air	2.7	1.8	--	2.5	2.3	9.3
36	Flush Oil	1.0	7.0	--	3.8	3.4	15.2
37	Solid Waste	2.4	--	--	--	--	2.4
40	Site Dev.	--	--	75.0	--	--	75.0
41	Buildings/DCS	--	24.5	46.0	--	--	70.5
42	Telecomm	--	2.0	--	--	--	2.0
	TOTALS FROM PAGE 1	251.2	140.8	18.2	113.5	102.3	626.0
	GRAND TOTAL	267.9	191.6	140.1	142.4	128.4	870.4

Spare plants = None

41.2 ISBL Installed Plant Costs

ISBL installed plant costs for the complex were calculated by 1) taking the estimated ISBL plant cost for each ISBL plant, 2) adding to that the respective proportional amount of total OSBL costs and then 3) adding the proportional amount of home offices, engineering fee and contingency. Results are shown in Table 41.2. This table also includes the number of trains (operating and total number) for each plant.

Table 41.2

ISBL Installed Plant Costs

CAPITAL COST FOR THE COMPLEX BASE LINE FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	91000	126400	157800
1.4	10	12	105000	146000	182100
2	5	6	1118600	1554900	1940700
3	1	1	25300	35100	43800
4	1	1	15600	21700	27100
5	1	1	74000	102800	128300
6	1	1	152600	212200	264800
8	1	1	42200	58700	73300
9	5	6	316300	440000	548700
10	5	5	191000	265500	331400
11	4	4	46700	64900	81000
38	1	1	40100	55800	69600
39	1	1	13300	18500	23100
TOTAL			2231700	3102500	3871700

41.3 Ov rall Plant Costs

The overall plant costs and account-by-account breakdowns are summarized in Table 41.3.

Table 41.3

ESTIMATED OVERALL COST SUMMARY FOR COAL LIQUEFACTION COMPLEX

FIRST PLANT

(2ND QUARTER, 1991 $MILLION)

Item	1st Plant
Major Equipment	1029.8
Bulk Materials	701.2
Subcontracts	210.6
Direct Labor	613.3
Subtotal Direct Cost	2554.9
Distributable Costs	547.0
Subtotal Indirect Costs	547.0
Total Field Cost (Direct & Indirect)	**3101.9**
Home Office & Fee	327.9
Contingency	441.9
Total Plant Costs	**3871.7**

NTH PLANT OVERALL CAPITAL COSTS (BASELINE)

42. Nth Plant Ov rall Capital Costs (Baseline)

The Nth plant overall capital cost estimates (baseline) for the entire complex are presented in this section. The estimate basis, methodology and accuracy are presented in Section 3.0 of Volume I of this report.

The inside battery limits (ISBL) and outside battery limits (OSBL) plant field costs and breakdowns are summarized in Sections 42.0 and 42.1 respectively. These same field costs and breakdowns are given in the appropriate capital cost sections of each plant throughout Volumes I and II of this report.

Section 42.2 presents the ISBL plants on installed basis. The ISBL installed basis costs includes the following costs:

- Field costs of ISBL plants
- Field costs of OSBL plants
- Home office costs and fees
- A suitable contingency

The above costs, when added together become the total installed cost of the complex. These costs (field costs of OSBL plants, Home office costs and fees and a suitable contingency) have been allocated to the ISBL plants. In this fashion, each ISBL plants cost can now be expressed on "Installed" basis. Such allocation of costs and the resulting installed costs for each plant and for the entire complex are shown in Table 42.2.

Section 42.3 presents the overall plant installed costs of Section 42.2 on an account-by account basis. Table 42.3 includes the overall Home office and fees as well as the contingencies estimated for the total complex.

Obviously, Sections 42.2 and 42.3 present the same bottom line overall installed cost of the complex in two different ways. This installed cost for the Nth Plant based on second quarter 1991 datum is $3491.2 million dollars. No project escalation is included in this figure for disbursement of this cost over the life of this project. Such escalation will be addressed in the economics section, Volume III, of this report.

42.O ISBL Plant Field Cost Summaries

The ISBL plant field costs for the entire complex are developed by estimating the field costs of each process plant. The field cost for each plant is comprised of 1) major equipment, 2) bulk materials, 3) subcontracts, 4) direct labor and 5) distributables. Costs data thus developed are shown in Table 42.0.

Table 42.0
Estimated Total Field Costs
for Coal Liquefaction Complex - Process Units (ISBL)
(2nd Quarter 1991 $Million)
Nth Plant

Plant No.	Process Units	Major Equipment	Bulk Materials	Sub-contracts	Direct Labor	Distribu-tables	Total Field Costs
1	Coal Handling	34.8	19.7	--	19.2	17.3	91.0
1.4	Coal Crushing	31.5	19.8	4.5	16.7	15.0	87.5
2	Coal Liquefaction	287.0	233.0	17.0	208.0	187.2	932.2
3	Gas Plant	8.3	5.8	0.9	5.4	4.9	25.3
4	Naphtha Hydrog.	5.2	3.5	0.5	3.4	3.0	15.6
5	Gas\Oil Hydro.	24.8	16.9	2.7	15.6	14.0	74.0
6	H_2 Purification	61.0	31.0	3.6	30.0	27.0	152.6
8	ROSE Unit	13.0	10.0	4.0	8.0	7.2	42.2
9	H_2 From Coal	81.5	62.7	10.6	57.3	51.6	263.7
10	Air SEP	104.0	20.0	17.0	29.0	21.0	191.0
11	Sulfur Plant	15.2	10.4	1.8	10.2	9.1	46.7
38	NH3 Recovery	12.4	9.9	1.3	8.7	7.8	40.1
39	Phenol 11	3.5	3.7	0.2	3.1	2.8	13.3
	TOTALS	682.2	446.4	64.1	414.6	367.9	1975.2

Spare Plants = None

42.1 OSBL Plant Field Cost Summaries

The OSBL plant field costs for the entire complex are developed by estimating the field costs of each offsite/utilities plant. The field cost for each plant is comprised of 1) major equipment, 2) bulk materials, 3) subcontracts, 4) direct labor and 5) distributables. Results thus obtained are shown in Table 42.1.

Table 42.1
Estimated Total Field Costs
for Coal Liquefaction Complex - Offsites/Utilities (OSBL)
(2nd Quarter 1991 $Million)
Nth Plant

Plant No.	Offsite Units	Major Equipment	Bulk Materials	Sub-contracts	Direct Labor	Distribu-tables	Total Field Costs
19	Relief & Blowdown	2.0	1.5	0.1	1.4	1.3	6.3
20	Tankage	38.0	25.5	3.4	22.3	20.1	109.3
21	Interconn. Piping	--	23.5	4.0	22.5	20.3	70.3
22	Product Shipping	0.2	0.3	0.1	0.1	0.1	0.8
23	Tank Car/Truck	2.0	3.4	0.7	3.2	2.9	12.2
24	Ash Disposal	11.1	4.8	1.5	6.0	5.4	28.8
25	Catalyst & Chemicals	--	--	0.3	--	--	0.3
30	Electrical Distribution	--	41.0	--	18.0	16.2	75.2
31	Steam & Power	180.4	33.3	3.2	33.2	29.9	280.0
32	Water	17.5	7.5	4.9	6.8	6.1	42.8
	SUBTOTALS	251.2	140.8	18.2	113.5	102.3	626.0

Spare Plants = None

Tabl 42.1 - continued

Estimated Total Field Costs
for Coal Liquefaction Complex - Offsites/Utilities (OSBL)
(2nd Quarter 1991 $Million)
Nth Plant

Plant No.	Offsite Units	Major Equipment	Bulk Materials	Sub-contracts	Direct Labor	Distribu-tables	Total Field Costs
33	Fire Protection	2.7	5.3	0.2	7.5	6.8	22.5
34	Sewage	7.9	10.2	0.7	15.1	13.6	47.5
35	Instr/Plant Air	2.7	1.8	--	2.5	2.3	9.3
36	Flush Oil	1.0	7.0	--	3.8	3.4	15.2
37	Solid Waste	2.4	--	--	--	--	2.4
40	Site Dev.	--	--	75.0	--	--	75.0
41	Buildings/DCS	--	24.5	46.0	--	--	70.5
42	Telecomm	--	2.0	--	--	--	2.0
	TOTALS FROM PAGE 1	251.2	140.8	18.2	113.5	102.3	626.0
	GRAND TOTAL	267.9	191.6	140.1	142.4	128.4	870.4

Spare plants = None

42.2 ISBL Installed Plant Costs

ISBL installed plant costs for the complex were calculated by 1) taking the estimated ISBL plant cost for each ISBL plant, 2) adding to that the respective proportional amount of total OSBL costs and then 3) adding the proportional amount of home offices, engineering fee and contingency. Results are shown in Table 42.2. This table also includes the number of trains (operating and total number) for each plant.

Table 42.2

ISBL Installed Plant Costs

CAPITAL COST FOR THE COMPLEX
BASE LINE FOR THE NTH PLANT

Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	91000	131000	160800
1.4	10	10	87500	126000	154600
2	5	5	932200	1343000	1647800
3	1	1	25300	36400	44700
4	1	1	15600	22500	27600
5	1	1	74000	106500	130700
6	1	1	152600	220000	269800
8	1	1	42200	60800	74600
9	5	5	263700	380000	465900
10	5	5	191000	275000	337700
11	4	4	46700	67200	82500
38	1	1	40100	57800	71000
39	1	1	13300	19200	23500
TOTAL			1975200	2845400	3491200

42.3 Overall Plant Costs

The overall plant costs and acount-by-account breakdowns are summarized in Table 42.3 below.

Table 42.3

Overall Cost Summary
For Coal Liquefaction Complex

Nth PLANT

(2ND QUARTER, 1991 $MILLION)

Item	Nth Plant
Major Equipment	950.1
Bulk Materials	638.0
Subcontracts	204.2
Direct Labor	557.0
Subtotal Direct Cost	2349.3
Distributable Costs	496.3
Subtotal Indirect Costs	496.3
Total Field Cost (Direct & Indirect)	**2845.6**
Home Office & Fee	240.5
Contingency	405.1
Total Plant Costs	**3491.2**

DEFINITION OF OPTIONS TO BASELINE DESIGN

43. Definition of Options to Bas line Design

43.0 Methodology for Selection

There are several key process features needed to be addressed in selecting the options. These key process features are 1) coal cleaning method, 2) reactor configuration, 3) vacuum bottoms processing and 4) method of hydrogen production. The variables related to each of these process features are listed in Table 43.1. For reader's reference, the process variables/features of the baseline design are given in Table 43.2.

The methodology utilized to select the options is explained below. As shown in Tables 43.1 through 43.8 six options were selected. Each of the selected six options was developed following a case study approach, as described below.

- Identify the primary process features and variables related to each process feature (Table 43.1)
- Define the baseline design by selecting the agreed upon combination of process variables/features as shown in Table 43.2.
- Define each option by changing the variable of one process feature at a time, maintaining the variables of other process features unchanged
- Combination of the newly defined process features defines the respective option
- Various options thus defined are shown in Tables 43.3 through 43.8.

Besides these six options, an additional option, Option 7, was incorporated in the study as an extension of the original scope of the study. In this option a naphtha reformer, Plant 7, is added to the baseline design downstream of the naphtha hydrotreater (Plant 4 of the base case) to produce a 95 RON clear reformate product.

TABLE 43.1

PROCESS FEATURES AND RELATED VARIABLES

Process Features:	Variables:
Cleaning Method for Feed Coal	• Jig • Heavy Media Separation • Spherical Agglomeration
Reactor Configuration	• Catalytic-Catalytic • Thermal-Catalytic • Catalytic-Catalytic with Vent Gas Separation
Vacuum Bottoms Processing	• ROSE-SR • Coking Delayed Fluid
Hydrogen Production	• Coal Gasification (1) Shell Texaco • Steam Reforming of Natural Gas

(1) Will include ROSE-SR concentrate or coke where applicable

TABLE 43.2

PROCESS FEATURES AND RELATED VARIABLES FOR BASE LINE DESIGN

Process Features:	Variables:
Cleaning Method for Feed Coal	Jig
Reactor Configuration	Catalytic-Catalytic
Vacuum Bottoms Processing	ROSE-SR
Hydrogen Production	Coal + ROSE Concentrate Gasification Utilizing TEXACO Technology (2)

(2) Selection (Shell vs Texaco) was based on economics and engineering judgement

TABLE 43.3

PROCESS FEATURES AND RELATED VARIABLES FOR OPTION 1

Process Features:	Variables:
Cleaning Method for Feed Coal	Heavy Media Separation (3)
Reactor Configuration	Catalytic-Catalytic
Vacuum Bottoms Processing	ROSE-SR
Hydrogen Production	Coal + ROSE-SR Concentrate Gasification Utilizing TEXACO Technology

(3) Coal reactivity is assumed to be same as that of the base case coal

TABLE 43.4

PROCESS FEATURES AND RELATED VARIABLES FOR OPTION 2

Process Features:	Variables:
Cleaning Method for Feed Coal	Spherical Agglomeration (3)
Reactor Configuration	Catalytic-Catalytic
Vacuum Bottoms Processing	ROSE-SR
Hydrogen Production	Coal + ROSE Concentrate Gasification Utilizing TEXACO Technology

(3) Coal reactivity is assumed to be same as that of the base case coal

TABLE 43.5

PROCESS FEATURES AND RELATED VARIABLES FOR OPTION 3

Process Features:	Variables:
Feed Coal	Cleaning by Jig
Reactor Configuration	Thermal-Catalytic
Vacuum Bottoms Processing	ROSE-SR
Hydrogen Production	Coal + ROSE-SR Concentrate Gasification Utilizing TEXACO Technology

TABLE 43.6

PROCESS FEATURES AND RELATED VARIABLES FOR OPTION 4

Process Features:	Variables:
Feed Coal	Cleaning by Jig
Reactor Configuration	Catalytic-Catalytic with Vent Gas Separation
Vacuum Bottoms Processing	ROSE-SR
Hydrogen Production	Coal + ROSE Concentrate Gasification Utilizing TEXACO Technology

TABLE 43.7

PROCESS FEATURES AND RELATED VARIABLES FOR OPTION 5

Process Features:	Variables:
Feed Coal	Cleaning by Jig
Reactor Configuration	Catalytic-Catalytic
Vacuum Bottoms Processing	Fluid Coking (4,5)
Hydrogen Production	Coal + Coke Gasification Gasification Utilizing TEXACO Technology

(4) With DOE/PETC's approval, delayed coking option as shown in Table 1 has been deleted from the scope of work. Exxon fluid coking technology was selected as the only coking technology for the study.

(5) Coke is sent to gasifier.

TABLE 43.8

PROCESS FEATURES AND RELATED VARIABLES FOR OPTION 6

Process Features:	Variables:
Feed Coal	Cleaning by Jig
Reactor Configuration	Catalytic-Catalytic
Vacuum Bottoms Processing	ROSE-SR
Hydrogen Production	Steam Reforming of Natural Gas

(2) Ash concentrate is sent to fluid bed combustor

OPTION 1

44. Option 1 (Liqu faction F ed Coal Cleaning by Heavy Media Separation)

44.0 Design Basis, Criteria and Considerations

In this option, as discussed earlier, the feed coal to the liquefaction reactor is cleaned by a heavy medium separation technique instead of Jig cleaning (baseline case). The coal feed to the gasifier, however, is cleaned by Jigging (same as the base case).

The design basis, criteria and considerations for Plant 1 of this option are the same as the base case with a few exceptions. These exceptions are mentioned below.

Ash content of clean coal:	8.6 wt%, dry basis
Product size from Plant 1:	Shown below in Table 44.1.

Table 44.1
Product Size From Plant 1

Particle Size	Wt%
1-1/2" x 1/4"	59.9
1/4" x 28 M	35.1
28M x 100M	5.0
Moisture	9.0

The directly affected plant for this option is the coal cleaning and handling plant (Plant 1). The indirectly affected plants are: coal grinding and drying plant (Plant 1.4), atmospheric and vacuum towers of the coal liquefaction plant (Plant 2), critical solvent deashing unit (Plant 8), hydrogen production plant (Plant 9), steam and power generation plant (Plant 31), sewage and water treatment plant (Plant 34), ammonia recovery plant (Plant 38) and phenol recovery plant (Plant 39).

In developing this option several key assumptions were made. These are:
1) The reactivity of coal (on MAF basis) in the liquefaction reactor is same as that of the base case coal, which means that the conversion and the product slate from the liquefaction reactor section are same as those for the base case. This is a very weak assumption. However, in the absence of any suitable and available data it was decided that this assumption was the only reasonable alternative.
2) Vacuum tower bottoms stream has the same composition as the base case.
3) 850+ fraction is removed from the vacuum tower by adding a side draw at a lower section of the vacuum tower and the fraction is sent to the gasifier, Plant 9.

44.1 Capital Costs (First & Nth Plants)

The total installed cost for each option (Options 1 through 6) was re-estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 44.2 and 44.3 for the First & Nth plant scenarios are those for the entire complex operating in the option one mode.

For this option the directly affected plant is the coal cleaning and handling plant (Plant 1).

Table 44.2

Capital Costs (First Plant)

CAPITAL COST FOR THE COMPLEX OPTION 1 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	127600	175100	218600
1.4	10	12	102500	140700	175600
2	5	6	1060000	1455200	1816300
3	1	1	25300	34700	43300
4	1	1	15600	21400	26700
5	1	1	74000	101500	126700
6	1	1	152600	209600	261600
8	1	1	36700	50400	62900
9	5	6	369000	506600	632200
10	5	5	191000	262200	327300
11	4	4	58300	80100	100000
38	1	1	40100	55000	68600
39	1	1	13300	18200	22700
	TOTAL		2266000	3110700	3882500

Table 44.3

Capital Costs (Nth Plant)

CAPITAL COST FOR THE COMPLEX OPTION 1 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	127600	175100	214800
1.4	10	10	85400	117300	143900
2	5	5	883300	1212700	1487900
3	1	1	25300	34700	42600
4	1	1	15600	21400	26300
5	1	1	74000	101500	124600
6	1	1	152600	209600	257100
8	1	1	36700	50400	61900
9	5	5	263600	361800	443900
10	5	5	191000	262200	321800
11	4	4	46700	64100	78600
38	1	1	40100	55000	67500
39	1	1	13300	18200	22300
	TOTAL		1955200	2684000	3293200

44.2 Delta Operating Requirements

In general the operating requirements are 1) labor, 2) raw materials, 3) catalyst and chemicals, and 4) utilities. In calculating the operating requirements for any option (except Options 3, 6 and 7) it was assumed that the labor and catalyst and chemicals requirement remained the same as in the base case. So the delta operating requirements for this option * consist of raw materials and utilities. These are shown below:

Delta Raw Materials:

Feed Coal: 412 TPSD

Delta Utilities:

Water: 2 gpm

Natural gas: (38)** MM BTU/HR.

---

* Defined as the requirements for the option minus the requirements for the base case.

** ( ) Indicates negative quantity

OPTION 2

45. Option 2 (Liqu faction Feed Coal Cleaning by Spherical Agglom ration)

45.0 Design Basis, Criteria and Considerations

In this option, as discussed earlier, the feed coal to the liquefaction reactor is cleaned by a Spherical Agglomeration technique instead of Jig cleaning (baseline case). The coal feed to the gasifier, however, is cleaned by Jigging (same as the base case).

The design basis, criteria and considerations for Plant 1 of this option are the same as the base case with a few exceptions. These exceptions are mentioned below.

Ash content of clean coal:	3.8 wt%, dry basis
Product size from Plant 1:	Shown in below

Particle Size	Wt%
1-1/2" x 28	34.7
3/8" (agglomerates)	65.3
Moisture	10.8

The directly affected plant for this option is the coal cleaning and handling plant (Plant 1). The indirectly affected plants are: coal grinding and drying plant (Plant 1.4), atmospheric and vacuum towers of the coal liquefaction plant (Plant 2), critical solvent deashing unit (Plant 8), hydrogen production plant (Plant 9), steam and power generation plant (Plant 31), sewage and water treatment plant (Plant 34), ammonia recovery plant (Plant 38) and phenol recovery plant (Plant 39).

In developing this option several key assumptions were made. These are:
1) The reactivity of coal (on MAF basis) in the liquefaction reactor is same as that of the base case coal, which means that the conversion and the product slate from the liquefaction reactor section are same as those for the base case. This is a very week assumption. However, in the absence of any suitable and available data it was decided that this assumption was the only reasonable assumption.
2) Vacuum tower bottoms stream has the same composition as the base case.
3) 850+ fraction is removed from the vacuum tower by adding a side draw at a lower section of the vacuum tower and the fraction is sent to the gasifier, Plant 9.

45.1 Capital Costs (First & Nth Plants)

The total installed cost for each option (Options 1 through 6) was re-estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 45.1 and 45.2 for the First & Nth plant scenarios are those for the entire complex operating in the option two mode.

For this option the directly affected plant is the coal cleaning and handling plant (Plant 1).

Table 45.1

Option 2

CAPITAL COST FOR THE COMPLEX OPTION 2 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	368900	506400	632000
1.4	10	12	101500	139400	173900
2	5	6	967300	1327900	1657400
3	1	1	25300	34700	43300
4	1	1	15600	21400	26700
5	1	1	73900	101500	126700
6	1	1	152600	209600	261600
8	1	1	27600	37800	47200
9	5	6	369000	506600	632200
10	5	5	191000	262200	327300
11	4	4	58300	80100	100000
38	1	1	39900	54800	68400
39	1	1	13200	18100	22600
	TOTAL		2404100	3300500	4119300

Table 45.2

Option 2

CAPITAL COST FOR THE COMPLEX OPTION 2 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	368900	506400	621300
1.4	10	10	84600	116100	142500
2	5	5	806100	1106600	1357700
3	1	1	25300	34700	42600
4	1	1	15600	21400	26300
5	1	1	74000	101500	124600
6	1	1	152600	209600	257100
8	1	1	27500	37800	46400
9	5	5	263600	361800	444000
10	5	5	191000	262300	321800
11	4	4	46700	64100	78600
38	1	1	39900	54800	67200
39	1	1	13200	18100	22200
	TOTAL		2109000	2895200	3552300

45.2 D lta Operating Requir ments

In general the operating requirements are 1) labor, 2) raw materials, 3) catalyst and chemicals, and 4) utilities. In calculating the operating requirements for any option (except Options 3, 6 and 7) it was assumed that the labor and catalyst and chemicals requirement remained the same as in the base case. So the delta operating requirements for this option * consist of raw materials and utilities. These are shown below:

Delta Raw Materials:

Feed Coal:	(888)** TPSD

Delta Utilities:

Water:	874 gpm
Natural gas:	846 MM BTU/HR.

---

* Defined as the requirements for the option minus the requirements for the base case.

** ( ) Indicates negative quantity

OPTION 3

46. Option 3 (Thermal-Catalytic Liquefaction Reactor Configuration)

46.0 Design Basis, Criteria and Considerations

In this option, as discussed earlier, the reactor configuration is changed from the base case configuration (catalytic-catalytic) to thermal-catalytic, where first stage is the thermal reactor and second stage is the catalytic reactor.

This option was developed utilizing the following methodology for reactor sizing:

Use Wilsonville Run 250 D for operating conditions, conversion and yields. The coal liquefaction overall yield is shown in Table 46.1.

Maintain total coal feed rate through Plant 2 (Coal Liquefaction Plant) is the same as in base case.

Compare the space velocity (based on catalyst volume) of the baseline second stage catalytic reactor with this option (1.12 vs 0.72 Lb MAF Coal/Hr./LB catalyst, respectively). Refer to Table 46.2.

Calculate the reactor volume and the number of reactor trains to account for the change in space velocity mentioned above for the second stage reactor (catalytic). Note that directionally the reactor volume per train will be higher than the base case. Acording to HRI the reactor weight is the primary determinant for its maximum size and the number of reactor trains. Therefore, the number of reactor trains required for this option will be more than that for the base case.

Calculate the reactor height keeping the maximum allowable reactor diameter based on weight.

- Include the ebullating bed pump for the thermal reactor to induce proper mixing to avoid unacceptable axial temperature gradient.
- Calculate the corresponding coal throughput per train.
- Calculate the thermal reactor volume, (first stage) using Wilsonville experimental space velocity data (Run 250 D) and the number of required trains.
- Keep the diameter of the thermal reactor (first stage) the same as that of the catalytic reactor (second stage). Verify by using the gas velocity correlation. Since the diameter is known, calculate the height of the reactor from its previusly calculated volume.
- The wall thickness will be assumed to be same as the HRI baseline design. The potential minor difference is deemed to have insignificant impact on plant cost.

TABLE 46.1

COAL LIQUEFACTION YIELD

Yields wt% MAF Coal Feed	Overall
H_2S	3.34
H_2O	9.51
NH_3	1.63
CO	0.07
CO_2	0.16
C1	2.69
C2	2.09
C3	2.22
C4	0.79
C5-350°F	12.51
350-450°F	6.31
450-650°F	21.35
650-850°F	17.94
850-1000°F	5.00
1000°F+	13.08
Unconverted Coal	7.21
Phenols	0.30
Ash	12.96
H2 Consumption	-6.20

TABLE 46.2

Comparison of Critical Parameters for Baseline and Therm-cat Option

Parameter	Baseline Design (Run 257E)	Thermal-Cat Option 3 (Run 250D)
Temp, °F		
Stage 1	790	825
Stage 2	760	740
Coal Space Velocity (Lb MAF Coal/Hr./Lb. Cat)		
Stage 1	1.12	(37.1)*
Stage 2	1.12	0.72

* The number in parenthesis is in Lb MAF Coal/Hr./Cubic Ft. Reactor Volume.

The directly affected plant is, of course, the liquefaction plant, Plant 2. The indirectly affected plants are all the remaining plants in the complex.

In developing this option a key assumption was made. This assumption is:

> Extra 850 - 1000° F (as compared to the base case yield) is removed from the vacuum tower by adding a side draw at a lower section of the vacuum tower. The side draw stream is sent to the gasifier, Plant 9. This allows the same composition of feed to Plant 8, the critical solvent deashing unit (Kerr McGee's ROSE SR technology)

Reactor sizing of both reactors (first stage thermal and second stage catalytic) of the directly affected plant (Plant 2) are shown in Table 46.3.

TABLE 46.3

REACTOR SIZING

Service	Dia. (ID)[1] Ft.	Length Ft.	Thickness Inches	Weight ST	Number of Trains
First Stage Reactor	15	38	11.6	550	7
Second Stage Reactor	15	90	11.6	1300	7

Material of Construction: (the same as the base case)
2-1/4% Cr., 1% Mo with 374SS overlay, refractory lined (6" thick).

(1) Metal inside diameter

46.1 Capital Costs (First & Nth Plants)

The total installed cost for each option (Options 1 through 6) was re-estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 46.4 and 46.5 for the First & Nth plant scenarios are those for the entire complex operating in the option three mode.

For this option the directly affected plant is the coal liquefaction plant (Plant 2).

Table 46.4

Option 3

CAPITAL COST FOR THE COMPLEX OPTION 3 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	86600	118900	148400
1.4	10	12	105000	144100	179900
2	7	8	1139200	1563900	1952000
3	1	1	23800	32600	40700
4	1	1	12900	17700	22000
5	1	1	64800	88900	111000
6	1	1	161400	221600	276600
8	1	1	53700	73700	91900
9	5	6	311500	427700	533800
10	5	5	190700	261900	326800
11	4	4	43800	60100	75100
38	1	1	39800	54600	68200
39	1	1	13200	18100	22600
	TOTAL		2246400	3083800	3849000

Table 46.5

Option 3

CAPITAL COST FOR THE COMPLEX OPTION 3 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	86600	118900	145900
1.4	10	10	87500	120100	147300
2	7	7	996800	1368400	1679000
3	1	1	23800	32600	40100
4	1	1	12900	17700	21700
5	1	1	64800	88900	109100
6	1	1	161400	221600	271900
8	1	1	53700	73700	90400
9	5	5	259600	356400	437300
10	5	5	190700	261900	321300
11	4	4	43800	60100	73800
38	1	1	39800	54600	67000
39	1	1	13200	18100	22200
	TOTAL		2034600	2793000	3427000

46.2 Delta Operating Requirements

The operating requirements are 1) labor, 2, raw materials, 3) catalyst and chemicals, and 4) utilities. In this option there is no significant change in catalyst and chemicals requirement. There is, however, a change in the number of operators required and changes in raw materials and utilities requirements. The change in number of operators requirement is due to the increase in number of trains for Plant 2 from 5 for the baseline to 7 for this option. These changes are shown below as delta requirements for this option* :

Delta Operators: 21

Delta Raw Materials:

Feed Coal: (2,279)** TPSD

Delta Utilities:
Water: (151)** gpm
Natural gas: (162)** mm BTU/hr.

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* Defined as the requirement for the option mimus the requirements for the base case.

** ( ) Indicates negative quantity

OPTION 4

47. Option 4 (Catalytic-Catalytic Reactor Configuration with Vent Gas S paration)

47.0 Design Basis, Criteria and Considerations

In this option, as discussed earlier, the reactor configuration is changed from the base case configuration (catalytic-catalytic) to catalytic reactor for both the stages with inter stage vent gas separation. The design basis is same as the base case.

As discussed in Section 47 of Task II, Volume III, the use of interstage separation was not beneficial under the design basis conditions of this option.

47.1 Capital Costs (First & Nth Plants)

The total installed cost for each option (Options 1 through 6) was re-estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 47.2 and 47.3 for the First & Nth plant scenarios are those for the entire complex operating in the option four mode.

Table 47.1

Option 4

CAPITAL COST FOR THE COMPLEX OPTION 4 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	90900	124800	155800
1.4	10	12	105000	144100	179900
2	5	6	1118600	1535600	1916700
3	1	1	25300	34700	43300
4	1	1	15600	21400	26700
5	1	1	74000	101500	126700
6	1	1	152600	209600	261500
8	1	1	42200	58000	72400
9	5	6	316300	434200	541900
10	5	5	191000	262200	327300
11	4	4	46700	64100	80000
38	1	1	40100	55100	68800
39	1	1	13300	18300	22800
TOTAL			2231600	3063600	3823800

Table 47.2

Option 4

CAPITAL COST FOR THE COMPLEX OPTION 4 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	90900	124900	153200
1.4	10	10	87500	120100	147300
2	5	5	932200	1279700	1570100
3	1	1	25300	34700	42600
4	1	1	15600	21400	26300
5	1	1	74000	101500	124600
6	1	1	152600	209500	257100
8	1	1	42200	58000	71100
9	5	5	263600	361800	444000
10	5	5	191000	262200	321800
11	4	4	46700	64100	78600
38	1	1	40100	55100	67600
39	1	1	13300	18300	22400
TOTAL			1975000	2711300	3326700

47.2 D lta Operating Requirements

In general the operating requirements are 1) labor, 2) raw materials, 3) catalyst and chemicals, and 4) utilities. In calculating the operating requirements for any option (except Options 3, 6 and 7) it was assumed that the labor and catalyst and chemicals requirement remained the same as in the base case. Since the operating requirements for this option are the same as the baseline, the delta operating requirements for this option are zero.

OPTION 5

48. Option 5 (Fluid Coking of Vacuum Bottoms)

48.0 Design Basis, Criteria and Considerations

In this option, as discussed earlier, the vacuum bottoms processing step is changed from critical solvent extraction (Kerr McGee's ROSE-SR) to FLUID COKING (Exxon's Technology).

The directly affected plant in this case is the Kerr McGee's ROSE-SR plant (Plant 8) which is replaced with FLUID COKING plant (Plant 8-02). Indirectly affected plants are all other process plants in the complex.

The liquefaction reactor yield data were generated with the help of SEI at Wilsonville, Alabama and Amoco at Naperville, Illinois. The yield data as shown in Table 48.1 were utilized as the design basis for the material balance of the coal liquefaction plant (Plant 2).

In developing this option several key assumptions were made. These assumptions are:

> The gas oil fraction from the vacuum tower is recycled to maintain the same solvent to MAF coal ratio as the base case.
>
> The coker liquid is fractionated and mixed with the respective Plant 2 products for hydrotreating purpose. However, since the percentages of these liquids are very small (naphtha 2 wt% and gas oil 4 wt%) no changes in operating conditions of the naphtha and gas oil hydrotreaters are considered.
>
> Hydrotreater yields for both naphtha and gas oil are same as the base case.

As a result, the throughput capacities for Plant 4 (naphtha hydrotreater) and Plant 5 (gas oil hydrotreater) are changed to 78% and 79% respectively.

TABLE 48.1

FLUID COKING OPTION

COAL LIQUEFACTION YIELD

Yields wt% MAF Coal Feed

	Overall
H_2S	2.44
H_2O	8.3
NH_3	1.19
CO	0.05
CO_2	0.12
C1	1.61
C2	1.25
C3	1.34
C4	0.60
C5-350°F	12.40
350-450°F	5.72
450-850°F	35.87
850-1000°F	0.00
1000°F+	26.40
Unconverted Coal	7.21
Phenols	0.30
Ash	12.96
H2 Consumption	- 4.80

48.1 Capital Costs (First & Nth Plants)

The total installed cost for each option (Options 1 through 6) was re-estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 48.2 and 48.3 for the First & Nth plant scenarios are those for the entire complex operating in the option five mode.

Table 48.2

Option 5

CAPITAL COST FOR THE COMPLEX OPTION 5 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	80000	109900	137200
1.4	10	12	105000	144100	179900
2	5	6	1118600	1535600	1916600
3	1	1	21100	28900	36100
4	1	1	12900	17700	22000
5	1	1	61700	84800	105800
6	1	1	134400	184500	230300
8-02	1	1	161100	221100	276000
9	5	6	261300	358800	447800
10	5	5	164900	226400	282600
11	4	4	39500	54200	67600
38	1	1	37800	51900	64700
39	1	1	13100	18000	22500
	TOTAL		2211400	3035900	3789100

Table 48.3

Option 5

CAPITAL COST FOR THE COMPLEX OPTION 5 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	80000	109900	134800
1.4	10	10	87500	120100	147300
2	5	5	932200	1279700	1570100
3	1	1	21100	28900	35500
4	1	1	12900	17700	21700
5	1	1	61700	84800	104000
6	1	1	134400	184500	226400
8	1	1	161100	221100	271300
9	5	5	217800	299000	366800
10	5	5	164900	226400	277800
11	4	4	39500	54200	66500
38	1	1	37800	51900	63700
39	1	1	13100	18000	22100
	TOTAL		1964000	2696200	3308000

48.2 Delta Operating Requirem nts

In general the operating requirements are 1) labor, 2) raw materials, 3) catalyst and chemicals, and 4) utilities. In calculating the operating requirements for any option (except Options 3, 6 and 7) it was assumed that the labor and catalyst and chemicals requirement remained the same as in the base case. So the delta operating requirements for this option * consist of raw materials and utilities. These are shown below:

Delta Raw Materials:

Feed Coal: (5,615)** TPSD

Delta Utilities:

Water: (1871)** gpm

Natural gas: (899)** MM BTU/HR.

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* Defined as the requirements for the option minus the requirements for the base case.

** ( ) Indicates negative quantity

OPTION 6

49. Option 6 (Steam Reforming of Natural Gas Plus FBC Unit for Hydrog n Production)

49.0 Design Basis, Criteria and Considerations

In this option, as discussed earlier, the hydrogen production method is changed from coal gasification (Plant 9) to steam methane reforming (Plant 9-01).

The following assumptions/design bases were made to develop this option:

Ash concentrate from Plant 8 (Kerr McGee's ROSE-SR plant) is sent to the Fluidized Bed Combustion (FBC) plant to generate high pressure steam.

The Steam Reformer produces 99.9% pure hydrogen for the complex. A total of three 150 MMSCFD hydrogen trains are required.

The Fluid Bed Combustor (FBC) and the Steam Turbine Generator (STG) are designed so that 50% of the ash concentrate from Plant 8 is sent to a single FBC/STG train. Therefore, there are two FBC/STG trains with one additional spare train for plant reliability purposes.

The directly affected plant is Plant 9. In this case, hydrogen is produced by natural gas reforming instead of coal gasification. The air separation plant (Plant 10) is eliminated and there is inclusion of a Fluid Bed Combination (FBC) plant for the ROSE-SR bottoms. Indirectly affected plants are Plant 2 (Coal Liquefaction Plant), Plant 11 (By-Product Sulfur Recovery Plant), Plant 31 (Steam and power Generation Plant), Plant 34 (Sewage and Effluent Water Treatment Plant), Plant 38 (Ammonia Recovery Plant), and Plant 39 (Phenol Recovery Plant).

The reformer was developed as a licensed process with limited information supplied by KTI.

49.1 Capital Costs (First & Nth Plants)

The total installed cost for each option (Options 1 through 6) was re-estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 49.1 and 49.2 for the First & Nth plant scenarios are those for the entire complex operating in the option six mode.

For this option the directly affected plants are Plant 9, Air Separation Plant, (Plant 10) and the additional FBC plant (in Plant 31.4-01) for the ROSE-SR bottoms. For this option, as discussed earlier, the air separation plant is not a part of this complex.

Table 49.1

Option 6

CAPITAL COST FOR THE COMPLEX OPTION 6 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	75800	101600	129700
1.4	10	12	105000	140600	179600
2	5	6	1118400	1498500	1913400
3	1	1	25200	33800	43200
4	1	1	15600	20900	26700
5	1	1	74000	99100	126500
6	1	1	152400	204200	260700
8	1	1	42200	56600	72200
9-01	5	6	204300	273800	349600
11	4	4	29300	39300	50200
38	1	1	37900	50800	64800
39	1	1	16500	22100	28200
	TOTAL		1896600	2541300	3244800

Table 49.2

Option 6

CAPITAL COST FOR THE COMPLEX OPTION 6 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	75800	101600	124600
1.4	10	10	87500	117200	143800
2	5	5	932000	1248700	1532200
3	1	1	25200	33800	41500
4	1	1	15600	20900	25600
5	1	1	74000	99100	121600
6	1	1	152400	204200	250500
8	1	1	42200	56600	69400
9-01	5	5	204300	273700	335900
11	4	4	29300	39300	48200
38	1	1	37900	50800	62300
39	1	1	16500	22100	27100
TOTAL			1692700	2268000	2782700

49.2 D lta Operating Requirements

The operating requirements are 1) labor, 2) raw materials, 3) catalyst and chemicals, and 4) utilities. In calculating the operating requirements for any option (except Options 3, 6 and 7) it was assumed that the labor and catalyst and chemicals requirement remained the same as in the base case. For this option there is a significant change in the overall configuration of the system. This has caused changes, not only in raw materials and utilities, but also in the number of operators required. So the delta operating requirements for this option * consist of raw materials and utilities and operating labor. These are shown below:

Delta Operators:	(107**)
Delta Raw Materials:	
Feed Coal:	(7,659)** TPSD
Natural gas:	7,291 MM BTU/HR.
Delta Utilities:	
Water:	4,566 gpm
Natural gas:*	(445)** MM BTU/HR.
Electricity Power Produced	21.645 MW

* Note that this figure is for the utility portion of the natural gas consumption. There is an additional consumption of natural gas in Plant 9-01 (Hydrogen Production by Natural Gas Reforming Plant). This amount is shown above as a Delta Raw Material consumption.

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* Defined as the requirements for the option minus the requirements for the base case.

** ( ) Indicates negative quantity

OPTION 7

50. Option 7 (Naphtha Reformering)

50.0 Design Basis, Criteria and Considerations

This option is incorporated in the study as an extension of the scope of the current study which was duly approved by DOE/PETC via a recent contract change.

In this option, the Continuous Catalyst Regeneration (CCR) Platforming process licensed by UOP is used. The Naphtha Reformer, Plant 7, is added downstream of Naphtha Hydrotreater (Plant 4 of the Base Case) to produce a 95 RON clear reformate product.

This option was developed based on Bechtel's in-house data generated during Bechtel's study in 1986 for Amoco Corporation, "Amoco Coal Liquefaction Study". It is also based on the published information by Chevron Research Company, Richmond, California, (reference: "Aromatics Production from Coal Syncrudes", R.C. Robinson, H.A. Frumkin and R.F. Sullivan, Energy Progress, Vol 3, No. 3, 1983) and the proprietary UOP information utilized in a previous study by Bechtel in 1981 (Breckinridge Study).

In developing this option, the following assumptions were made:

- Hydrotreated naphtha from the Base Case is acceptable as a feedstock for this Reformer.

- The Hydrogen Production rate was prorated from the above Amoco Study which is based on the same product specification of 95 RON. The composition of the net hydrogen stream from the separator section of the reformer plant (Plant 7), however, was assumed to be the same as that of the Breckinridge study.

- The C1-C4 make was calculated based on Chevron's results for the Illinois H-Coal hydrotreated naphtha as presented in the above referenced Chevron study.

The directly affected plant is the new plant, the Naphtha Reformer, Plant 7. The indirectly affected plants are Plants 1, 3, 6, 9, 10, 11, 31, 32, 38, 39.

50.1 Capital Costs (First & Nth Plants)

The total installed cost for this was estimated from the baseline estimates by replacing the cost of the directly affected baseline plant with the cost of the optional plant. All other cost modifications impacting the indirectly affected plants were done using the cost vs capacity correlations.

Thus the installed costs reported in the last column of Tables 50.1 and 50.3 for the First & Nth plant scenarios are those for the entire complex operating in the option seven mode.

For this option the directly affected plant is the Naptha Reformer (Plant 7).

Table 50.1

Option 7

CAPITAL COST FOR THE COMPLEX OPTION 7 FOR THE FIRST PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	89300	122700	153100
1.4	10	12	105000	144100	179900
2	5	6	1118600	1535600	1916600
3	1	1	25800	35400	44200
4	1	1	15600	21400	26700
5	1	1	73900	101500	126700
6	1	1	161600	221800	276800
7	1	1	30700	42100	52600
8	5	6	42200	58000	72400
9	5	5	298100	409200	510700
10	4	4	180800	248200	309700
11	1	1	45600	62600	78100
38	1	1	39500	54200	67700
39	1	1	13300	18300	22800
	TOTAL		2240000	3075100	3838000

Table 50.2

Option 7

CAPITAL COST FOR THE COMPLEX OPTION 7 FOR THE NTH PLANT					
Plant #	Number of Operating Train	Total Number of Train	ISBL Plant Field Costs 1000$	ISBL Plant Adj. With OSBL Costs 1000$	Installed Plant Costs 1000$
1	5	5	89300	122600	150500
1.4	10	10	87500	120100	147300
2	5	5	932200	1279700	1570100
3	1	1	25800	35400	43400
4	1	1	15600	21400	26300
5	1	1	73900	101500	124600
6	1	1	161600	221800	272100
7	1	1	30700	42100	51700
8	1	1	42200	58000	71100
9	5	5	248400	341000	418400
10	5	5	180800	248200	304500
11	4	4	45600	62600	76800
38	1	1	39500	54300	66600
39	1	1	13300	18300	22400
	TOTAL		1986400	2727000	3345800

50.2 Delta Op rating Requirem nts

The operating requirements for this option are 1) labor, 2) raw materials, 3) catalyst and chemicals, and 4) utilities. These are shown below as delta requirementrs for this option*.

Delta Operators:	11
Delta Raw Materials:	
Feed Coal:	(857)** TPSD

Delta Catalyst:

Additional catalyst requirements for this option are due to includion of naphtha reformer plant, (Plant 7). The catalyst requirements were estimated based on the proprietory catalyst cost information. The estimated catalysts costs are shown below:

Initial charge, MM$	3.11
Annual cost MM$	0.22

Delta Utilities:

Water:	(334) ** gpm
Natural gas:	232 MM BTU/HR.

* Defined as the requirements for the option minus the requirements for the base case.

** ( ) Indicates negative quantity